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ORIGINAL PAPERS

THE DEVELOPMENT OF SOME JEWELRY ENAMELS[1]

By H. G. Wolfram and W. N. Harrison

ABSTRACT

A series of thirty-three enamels having a constant melted portion of 20 silica, 30 lead oxide and 5 soda, and a variable melted portion of 45 parts was prepared and applied as powder to shallow cells in copper plates. Several of this field were used as fluxes in producing some transparent colored enamels.

Besides details of technique, the most important conclusions are: (*a*) all the better enamels contained boric acid plus lead or silica or both in the variable portion; (*b*) those having the highest ratio of lead oxide to silica were superior; (*c*) in those containing soda or potash, the latter seemed more desirable; (*d*) enamels ground to pass 80-mesh but retained on 100-mesh sieves produced the best results; (*e*) the color produced by a given stain was affected by the composition of the enamel; (*f*) the gloss, texture and general appearance of the enamel were affected by the coloring agent.

Introduction

Art enameling for ornamental purposes is perhaps the oldest form of man's attempt to apply glass or glaze to metals. Out of this early form of enameling practiced by the old Egyptian civilization has grown the present-day industry of enameling cast iron and steel, by methods which are fairly well understood, but the technique of enameling jewelry, medallions, and objects of a similar nature is not so well understood. The grow-

[1] Published by permission of the Director of the Bureau of Standards of the U. S. Department of Commerce. Presented at the Atlantic City Meeting, Feb., 1924 (Enamel Division). Received Oct. 11, 1924.

ing demand for this latter type of enameled ware has developed many unique and beautiful objects on the market of today.

The Bureau of Standards has received numerous requests for information regarding the manufacture of jewelry enamels of the clear glass or cloisonné type and since the literature of the subject is so meager and generally devoid of specific information as to batch composition and technique of application, an investigation was undertaken at this Bureau in order to provide more information on this subject.

Review of Literature

Minneman[1] used, as a basis for his work, a formula for an enamel flux given in a publication by W. N. Brown[2] and although Brown gives this and several other formulas as typical of the trade, he adds that his treatise is general since compositions and processes of application of enamels are regarded as secrets by the trade and he recommends that the prepared enamels should be bought from dependable dealers.

Cunynghame,[3] Fisher,[4] and Maryon[5] in their respective writings state that jewelry enamels are essentially optical glasses of high lead content and gives several formulas for their preparation; nevertheless they also advocate that enamels should never be prepared by the enameler from the raw material, but should be purchased from some competent dealer.

Chapin,[6] Wethered,[7] Day[8] and Bowes,[9] write from artistic and historical points of view. The works are interesting but lacking in the details pertaining to composition and application. Bowes, however, gives several chemical analyses of Japanese enamels of the Middle Period.

Randau[10] treats the subject more from the standpoint of the manufacturer than any of the above authors, and gives several formulas and some general information on jewelry enamel, but the bulk of his work treats with enamels for iron and steel.

The enamels given in the references as yielding good results are limited

[1] Minneman, "Art Enameling on Metals," *Trans. Amer. Ceram. Soc.*, **13**, 514 (1911).

[2] Brown, "The Art of Enameling on Metal," Scott, Greenwood & Co., London.

[3] Cunynghame, "Art Enameling," and "European Enamels," A. Constable & Co., Ltd., and Methuen & Co., London.

[4] Fisher, "Enameling on Metal," The Studio, London.

[5] Maryon, "Metal Work and Enameling," Chapman & Hall, Ltd., London.

[6] Chapin, "How to Enamel Jewelry," J. Wiley & Son, New York.

[7] Wethered, "Mediaeval Craftsmanship and the Modern Amateur," Longmans, Green & Co.

[8] Day, "The Course of Art and Workmanship," B. T. Batsford, London.

[9] Bowes, "Japanese Enamels" (printed for private circulation).

[10] Randau, "Enamels and Enameling," Scott, Greenwood & Co., London.

to a relatively few types and are of widely different compositions as indicated in Table I.

TABLE I

MELTED COMPOSITIONS OF COLORLESS ENAMELS REPORTED AS GIVING GOOD RESULTS

Material	A[1]	B[2]	C[3]
Silica	25.50%	44.12%	55.70%
Lead oxide	71.42	35.70	38.20
Sodium oxide	3.08	4.08	6.10
Potassium oxide	...	7.03	...
Boric oxide	...	9.10	...

Preparation

Based on this table, thirty-three enamels were prepared, each of which consisted of a constant portion, in terms of melted weights, of fifty-five parts, namely: 20 silica, 30 lead oxide and 5 sodium oxide, and a variable portion, also in terms of melted weights, of forty-five parts. The forty-five parts of variable portion consisted of additions of oxides already contained in the constant portion or additions of other oxides which it was believed would contribute favorably to the appearance of the finished product. This gave a series or field of enamels which was divided into six distinct subdivisions, each representing a different percentage distribution of the variable constituents, an arrangement which facilitated a study of the effects produced by each component part. The batch compositions of the enamels are given in Table II, and the melted weights in Table III.

TABLE II

BATCH COMPOSITIONS OF JEWELRY ENAMELS (CALCULATED TO GIVE 100 PARTS MELTED)

No.	Silica parts	Red lead parts	Sodium nitrate parts	Potassium nitrate parts	Boric acid parts
1	35	46.1	54.8	....	....
2	35	46.1	13.7	32.2	....
3	35	46.1	13.7	....	26.6
4	35	30.8	54.8	32.2	....
5	35	30.8	54.8	....	26.6
6	35	30.8	13.7	32.2	26.6
7	20	46.1	54.8	32.2	....
8	20	46.1	54.8	....	26.6
9	20	46.1	13.7	32.2	26.6
10	20	30.8	54.8	32.2	26.6
11	50	46.1	13.7	....	....
12	50	30.8	54.8	....	....
13	50	30.8	13.7	32.2	....
14	50	30.8	13.7	....	26.6
15	20	61.5	54.8	....	....

[1] Brown, *Loc. cit.*

[2] Commercial.

[3] Cunynghame, *Loc. cit.*

TABLE II (*Continued*)

No.	Silica parts	Red lead parts	Sodium nitrate parts	Potassium nitrate parts	Boric acid parts
16	20	61.5	13.7	32.2	....
17	20	61.5	13.7	....	26.6
18	50	38.4	34.3	....	....
19	50	38.4	13.7	16.1	....
20	50	38.4	13.7	....	13.3
21	50	30.8	34.3	16.1	....
22	50	30.8	34.3	....	13.3
23	50	30.8	13.7	16.1	13.3
24	20	61.5	34.3	....	....
25	20	61.5	34.3	16.1	....
26	20	61.5	13.7	....	13.3
27	40	46.1	41.1	....	....
28	40	46.1	13.7	21.5	....
29	40	46.1	13.7	....	17.7
30	30	61.5	27.4	....	....
31	30	61.5	13.7	10.7	....
32	30	61.5	13.7	....	8.86
33	42.5	53.7	13.7	....	....

TABLE III

MELTED WEIGHTS OF JEWELRY ENAMELS

Constant portion 20 SiO_2, 30 PbO, $5Na_2O$ (parts); variable portion 45 (parts)

	Oxides					Rating of specimen with reference to			
No.	SiO_2 parts	PbO parts	Na_2O parts	K_2O parts	B_2O_3 parts	Bubbles	Attack on copper	General appearance	Final rating
1	35	45	20	..	..	1	2	1	4
2	35	45	5	15	..	2	2	3	7
3	35	45	5	..	15	4	4	4	12
4	35	30	20	15	..	1	2	2	5
5	35	30	20	..	15	3	3	3	9
6	35	30	5	15	15	2	4	4	10
7	20	45	20	15	..	4	2	2	8
8	20	45	20	..	15	3	4	4	11
9	20	45	5	15	15	4	4	4	12
10	20	30	20	15	15	1	1	1	3
11	50	45	5	..	..	1	3	2	6
12	50	30	20	..	..	1	1	1	3
13	50	30	5	15	..	2	2	2	6
14	50	30	5	..	15	2	4	4	10
15	20	60	20	..	..	3	2	2	7
16	20	60	5	15	..	3	2	2	7
17	20	60	5	..	15	4	4	4	12
18	50	37.5	12.5	..	..	2	3	3	8
19	50	37.5	5	7.5	..	2	3	3	8
20	50	37.5	5	..	7.5	4	2	3	9
21	50	30	12.5	7.5	..	3	2	2	7
22	50	30	12.5	..	7.5	2	4	4	10
23	50	30	5	7.5	7.5	2	3	3	8
24	20	60	12.5	7.5	..	4	2	1	7

25	20	60	12.5	..	7.5	1	2	2	5
26	20	60	5	7.5	7.5	4	3	2	9
27	40	45	15	..	..	1	2	2	5
28	40	45	5	10	..	1	3	3	7
29	40	45	5	..	10	2	3	3	8
30	30	60	10	..	..	1	2	2	5
31	30	60	5	5	..	3	3	3	9
32	30	60	5	..	5	4	4	4	12
33	42.5	52.5	5	..	..	3	2	2	7

The enamels prepared in batches of about 200 grams, were melted in crucibles in a small gas-fired crucible furnace and stirred when necessary to prevent segregation of the more refractory constituents during melting. The enamels which contained an excess of bubbles or portions of undissolved material were remelted. It was found that a single melt at a comparatively high temperature was more effective in producing a bubble-free enamel than repeated meltings at lower temperatures.

Usually molten enamels are poured into water to facilitate disintegration, but it was found that this procedure produced an undesirable amount of fine frit and, therefore, the enamels were cooled by pouring them onto a clean steel plate. They were then broken into small pieces and ground with a mortar and pestle to pass an 80-mesh sieve. The enamels prepared in this way, when applied to metal, contained an excess of fine bubbles which probably resulted from the rapid fusion of the fine particles over the surface making it difficult for the entrapped gas to escape, since the same enamel, from which the fines had been removed by rejecting the portions passing the 100-mesh sieve, produced much better results.

Although gold, silver and copper are commonly used as bases for jewelry enamels, copper only was used in this investigation because it is more easily obtained and it is known that enamels which work well on copper give equally good results on the noble metals, but the converse of this is not always true. One and one-half by two and one-half inch pieces of 18 gage sheet copper, in which shallow cells $^3/_4$-inch in diameter were made by stamping, were finally adopted as a satisfactory type of test plate after several trials were made with smaller cells. The plates were free from grease so the use of an alkaline cleaning solution was not necessary, but they were all pickled in hot dilute hydrochloric acid, rinsed in hot water and thoroughly dried previous to application of the enamel.

Application and Firing

It is customary in the application of opaque enamels to copper to use an organic bonding material to hold the enamel in place on the metal while it is being fired. The ordinary bonding materials are solutions of gum tragacanth, gum arabic or gum acacia, which are either mixed with the enamel or applied separately as a wash on the metal. It has been recom-

mended that such solutions should be very dilute so that the organic material will completely burn out during firing. Although it is necessary to use a bonding material when the piece is fired in a vertical position or when enamel is applied to both sides of the ware, none was used in the application of the enamels here studied, because all specimens were fired in a horizontal position after filling the cells level full with the dry enamel.

The enamels were fired in an electric furnace at a temperature of about 950°C (1742°F) for one and one-half to two and one-half minutes, depending on the nature of the enamel and its thickness.

After firing, the enamel was ground down flush with the top of the cell, using carborundum as an abrasive, and then polished with a buffer using tin oxide and jeweler's rouge.

TABLE IV

RESULTS ON COLORED ENAMELS

Coloring agent	Per cent	Color	Base flux No. 3 Gloss	Texture	Remarks
Commercial black oxide	5.0	Black	Very good	Very few pinholes	Pinholes very small
Potassium dichromate	3.0	Dark green	Very good	Very good	Aventurine, finely distributed crystals
Copper nitrate	10.0	Yellowish green	Very good	Few pinholes	
Red iron oxide	10.0	Very dark brown	Very good	Wavy	
Black cobalt oxide	0.05	None	Very good	Very good	Color burned out oxide per cent too low
Black cobalt oxide	0.10	None	Very good	Very good	
Potassium permanganate	10.0	Reddish purple	Very good	Very good	Unevenly colored
Sodium uranate	7.5	Light amber	Very good	Very good	Attractive
Sodium uranate	15.0	Dark amber	Very good	Very good	Attractive
Coloring agent	**Per cent**	**Color**	**Base flux No. 17 Gloss**	**Texture**	**Remarks**
Commercial black oxide	3.0	Black	Good	Few pinholes	Attractive
Potassium dichromate	2.0	Dark moss green	Very good	Few pinholes	Dirty color
Green chrome oxide	1.0	Brownish green	Scummy	Many pinholes	Unevenly colored
Copper nitrate	15.0	Dark green	Very good	Few pinholes	Spotted with brown
Black copper oxide	5.0	Yellowish green	Scummy	Pinholes	Spotted with brown
Red iron oxide	5.0	Dark brown	Very good	Very good	Attractive
Black cobalt oxide	0.2	Very light blue	Very good	Very good	Attractive
Black cobalt oxide	0.25	Light blue	Not good	Wavy	Not good color

Potassium permanganate	15.0	Reddish purple	Very good	Very good	Attractive
Manganese dioxide	7.0	Dark reddish purple	Very good	Few pinholes	Unevenly colored

Base flux No. 20

Coloring agent	Per cent	Color	Gloss	Texture	Remarks
Commercial black oxide	3.0	Black	Scummy	Very good	Very attractive
Potassium dichromate	2.0	Pea green	Very good	Very good	Very attractive
Green chrome oxide	1.0	Pea green	Very good	Very good	Very attractive
Copper nitrate	15.0	Dark brownish green	Good	Few pinholes	Not good color
Black copper oxide	5.0	Dark brown	Very good	Very few pinholes	Not good color
Red iron oxide	5.0	Mahogany	Very good	Spotted	Very attractive
Black cobalt oxide	0.25	Dark seal brown	Very good	Few pinholes	Not good color
Black cobalt oxide	0.30	Mixture of blue and brown	Good	Good	Not good color
Potassium permanganate	15.0	Light brown	Very good	Very good	Attractive
Manganese dioxide	7.0	Brown	Very good	Very good	Attractive
Sodium uranate	7.5	Light amber	Very good	Very good	Very attractive

Base flux No. 29

Coloring agent	Per cent	Color	Gloss	Texture	Remarks
Commercial black oxide	3.0	Black	Good	Pinholes	Attractive
Potassium dichromate	2.0	Moss green	Very good	Few pinholes	Attractive
Green chrome oxide	1.0	Moss green	Very good	Vew few pinholes	Attractive
Copper nitrate	15.0	Dirty green	Very good	Very few pinholes	Not good color
Black copper oxide	5.0	Dirty green	Good	Very few pinholes	Not good color
Red iron oxide	5.0	Mahogany	Very good	Very good	Very attractive
Black cobalt oxide	0.25	Very light blue	Good	Few pinholes	Very attractive
Black cobalt oxide	0.30	Very light blue	Good	Few pinholes	Very attractive
Potassium permanganate	15.0	Dark reddish purple	Very good	Few pinholes	Attractive unevenly colored
Manganese dioxide	7.0	Light reddish purple	Very good	Very good	Very attractive
Sodium uranate	7.5	Light amber	Very good	Very good	Very attractive

TABLE IV (*Continued*)

Coloring agent	Per cent	Color	Base flux No. 6 Gloss	Texture	Remarks
Commercial black oxide	3.0	Black	Very good	Very good	Attractive
Potassium dichromate	2.0	Moss green	Very good	Few pinholes	Attractive
Green chrome oxide	1.0	Moss green	Very good	Few pinholes	Attractive
Copper nitrate	15.0	Dark green	Very good	Very good	Spotted with brown
Black copper oxide	5.0	Dark green	Very good	Very good	Spotted with brown
Red iron oxide	5.0	Orange red	Very good	Few pinholes	Unevenly colored
Black cobalt oxide	0.25	Light blue	Very good	Good	Very attractive
Black cobalt oxide	0.30	Dark blue	Very good	Very good	Very attractive
Potassium permanganate	15.0	Brownish black	Very good	Few pinholes	Very hard to burn
Manganese dioxide	7.0	Reddish purple	Very good	Very good	Unevenly colored
Sodium uranate	7.5	Light yellow	Very good	Few pinholes	Attractive

Coloring agent	Per cent	Color	Base flux No. 14 Gloss	Texture	Remarks
Commercial black oxide	3.0	Black	Good	Pinholes	Attractive
Potassium dichromate	2.0	Moss green	Very good	Very good	Very attractive
Green chrome oxide	1.0	Moss green	Very good	Very good	Very attractive
Copper nitrate	15.0	Dirty brown	Scummy	Pinholes	Not good
Black copper oxide	5.0	Dirty brown	Scummy	Pinholes	Not good
Red iron oxide	5.0	Brown	Scummy	Pinholes	Not good
Black cobalt oxide	0.25	Very light blue	Very good	Few pinholes	Attractive
Black cobalt oxide	0.30	Light blue	Very good	Few pinholes	Very attractive
Potassium permanganate	15.0	Dark brown	Scummy	Pinholes	Not good
Manganese dioxide	7.0	Reddish purple	Very good	Very good	Unevenly colored
Sodium uranate	7.5	Light amber	Very good	Very good	Attractive

Coloring agent	Per cent	Color	Base flux No. 32 Gloss	Texture	Remarks
Commercial black oxide	3.0	Black	Very good	Very good	Very attractive
Potassium dichromate	2.0	Dark green	Very good	Very good	Very attractive

Green chrome oxide	1.0	Dark green	Very good	Very good	Very attractive
Copper nitrate	15.0	Brownish green	Very good	Very good	Somewhat spotted
Copper oxide	5.0	Brownish green	Very good	Very good	Somewhat spotted
Red iron oxide	5.0	Reddish brown	Very good	Very good	Very attractive
Black cobalt oxide	0.25	Light blue	Very good	Very good	Very attractive
Black cobalt oxide	0.30	Light blue	Very good	Very good	Very attractive
Potassium permanganate	15.0	Wine color	Very good	Very good	Very attractive
Black manganese oxide	7.0	Light brown	Very good	Very good	Very attractive
Sodium uranate	7.5	Light yellow	Very good	Very good	Very attractive

Colored Enamels The colored enamels were prepared by taking as base fluxes colorless enamels Nos. 3, 6, 14, 17, 20, 29 and 32 (Table III) which represent a rather wide range in composition and at the same time include some of the best colorless enamels obtained. The preparation, application and firing were the same as for the colorless type except that a stain in the form of metallic salts or oxides was added to the raw batch before melting. The percentage of coloring ingredient used and the results obtained are given in Table IV.

Results

Colorless Enamels The effects of the different variable constituents upon the properties of the fired specimens are shown in Table III. The finished specimens were rated numerically according to: (*a*) general appearance, (*b*) freedom from bubbles, and (*c*) freedom from attack on the copper, since these were the chief factors affecting the quality of the enamel. The best were rated at four and the poorest at one. The most satisfactory enamel, then, has a rating of twelve found in the column headed, "Final Rating."

The relative desirability of various ratios of lead oxide and silica both to each other and to the other variable constituents, can be seen by comparing the several groups of enamels, considering as a group all the enamels in which the ratio of lead oxide to silica is constant. As the data in Table III show, the enamels containing only lead oxide and silica in the variable portion (Nos. 11 and 33) were not very satisfactory. However, all the satisfactory enamels include one or both of these constituents in the variable portion and the only enamel which does not contain either (No. 10) is one of the two least promising included in this study.

Concerning the enamels which did contain silica or lead oxide or both in the variable portion, it was observed that: (*a*) the four groups con-

sisting of enamels Nos. 7, 8, 9; 30, 31, 32; 15, 16, 17; and 1, 2, 3 (Table III) produced the best results and are among those in which the ratio of lead oxide to silica is the highest; (*b*) the three groups consisting of Nos. 21, 22, 23; 4, 5, 6; and 12, 13, 14 produced some good enamels; (*c*) the two groups consisting of Nos. 18, 19, 20; and 24, 25, 26 show less variation in quality as the constituents are substituted one for another and the enamels of these groups are only fair; (*d*) the group consisting of enamels Nos. 27, 28, 29 does not contain any very satisfactory enamel. No. 29 was the best of this set.

The relative effects of soda, potash and boric acid upon the qualities of the fired specimens can be seen by comparing the enamels in the groups having constant lead oxide-silica ratios. Such comparison shows there is a decided tendency for progressive improvement in the elimination of bubbles and the reduction of attack on the copper as potash was substituted for soda and boric acid in turn for potash. All the satisfactory enamels contained boric acid, which seemed to eliminate attack on the copper. This does not agree with the results obtained by some investigators of white enamels for copper, but their compositions vary considerably from the enamels studied in this work in that the white enamels contained opacifying materials. It is interesting to note, however, that the silica and lead oxide contents of the white enamels are within the limits indicated as satisfactory for the clear glass type of this investigation. Furthermore, the boric acid content of the above-mentioned white enamels is low, from which it may be concluded that other constituents were responsible for the attack on the copper. From these results it appears that the best enamels are obtained by substituting potash for soda, by the addition of boric acid and by increasing the lead content. The best colorless enamels obtained were Nos. 9, 32, 17, and 3 (Table III) and the next best were Nos. 8, 6, 14 and 22.

Colored Enamels As previously stated, the colored enamels were produced by adding metallic salts or oxides as the stain to a base of colorless enamel. Base enamels Nos. 3 and 17 (Table III) were chosen for the first work because of their superior qualities as colorless enamels. From the experience gained with these two, some new coloring agents were used and the per cent of others changed in subsequent experiments with colors as shown in Table IV.

In studying the results given in Table IV, it is evident that the composition of the enamel is an important factor in the production of satisfactory colors, for not only was the color produced by a given stain affected by the composition of the enamel used, but the coloring agents affected the gloss, texture and general appearance of the enamel.

It was noted in practically all cases where copper nitrate was used as the coloring stain that the time required for firing affected the shade of

color produced. This variation can probably be attributed to the changing states of oxidation of the copper in the enamel. There seemed to be practically no difference in the results obtained when chromium oxide was substituted for potassium dichromate or copper oxide for copper nitrate when this substitution was made giving equal amounts of the oxides in the melted enamel.

Conclusions

The following conclusions have been reached from the results obtained in this work:

1. Melting the enamel at a temperature high enough to produce a very fluid melt most effectively eliminated bubbles. In the case of highly refractory or viscous enamels remelting was beneficial.
2. Enamels ground to pass 80-mesh but retained on the 100-mesh sieve produced the best results on the fired specimens.
3. All the successful enamels contained boric acid with silica or lead oxide or both in the variable portion.
4. The best enamels were among those having the highest ratios of lead to silica.
5. In the enamels containing soda or potash, the latter seemed to be the more satisfactory.
6. The color produced by a given stain was affected by the composition of the enamel used.
7. The gloss, texture and general appearance of the enamel were affected by the coloring agent.
8. The oxides of chromium and copper may be substituted for the salts of these metals as stains without changing results.

COLORS IN A ZINC SILICATE GLAZE[1]

By Hobart M. Kraner

ABSTRACT

This represents a study of the effects of the seven common coloring oxides when introduced in a typical zinc silicate or willemite crystalline glaze. All the possible two- and three-color combinations for each colorant with a moderate color concentration and another similar series for strong color concentrations were investigated.

A new method by which fritting the glaze is obviated through the use of sodium silicate is described. The soluble sodium content is introduced by sodium silicate rather than by a frit.

Color absorption by the crystal was found to be most pronounced in the case of cobalt, decreasing in order with copper, manganese, iron, nickel, uranium and little, if any, absorption of chromium.

Description of color effects of most of these would be inadequate.

Introduction

In the literature of previous work considerable data are available giving formulas and firing behavior of the most practical and most easily produced crystalline glaze type, the zinc silicate or willemite glaze. Only scattered information is available, however, to show how the more interesting color effects may be obtained without a great deal of preliminary experimental work. This is to be regretted for the reason that the possible use of crystalline glazes in the decorative arts, such as that for which faience tile is being used, is extensive due to the rich textures obtainable.

In most cases where color has been used in such glazes, the color chosen seems to have been cobalt. From the results of this present study, it is somewhat obvious that this is probably due to the high luster of the glaze when this colorant is used and the completeness with which it is absorbed by the crystal, leaving a background glass of a different and contrasting color.

Clement[2] described his color study in zinc silicate glazes in which he obtained celadon green with CuO, blue with CoO, yellow-red with chromium, and Persian blue with blue crystals when nickel was used.

In Stull's[3] work some of the common coloring oxides were used, these being added to the glaze formula up to .05 equivalents. CoO, CuO, MnO, FeO were found to give pleasing effects. Chromium retarded or prevented crystallization.

Riddle[4] added 0.6% CuO to his glazes and obtained a turquoise blue, but this color, with copper, was probably produced by the influence of the RO constituents. He found MnO and FeO equally interesting.

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[1] Presented at the Atlantic City Meeting, Feb., 1924 (Art Division). Received Oct. 4, 1924.

[2] Clement, *Trans. Amer. Ceram. Soc.*, **4**, 38 (1902).

[3] Stull, *Trans. Amer. Ceram. Soc.*, **6**, 191 (1904)

[4] Riddle, *Trans. Amer. Ceram. Soc.*, **8**, 336 (1906).

Pukall[1] used a number of different coloring oxides including those of some of the rare metals such as tungsten, molybdenum and vanadium. Of the more common oxides he says, "colors may be chosen to suit except chromium."

The glazes described by Taxile Doat[2] are of the willemite type in which colors are derived from CoO, Fe_2O_3, and Fe_2O_3 contained in the rutile used. When he used chemically pure TiO_2 he obtained white crystals in many cases.

From the writer's experience it would seem that the fritting of the glaze is the most objectionable feature, inasmuch as it retards the production of these glazes by the artist or amateur who has only a small equipment available, rather than improper control of the firing and cooling involved. From a commercial standpoint this is also true in addition to the troubles attendant upon the use of a glaze which is 100% frit, and which must be applied through the use of gums or molasses. The application and firing problems are also multiplied inasmuch as during the heating-up period the gum is oxidized and the frail glaze powder often drops from the ware leaving bare spots which are not healed in many cases by the subsequent flowing of the glaze.

The process about to be described, although it has its objectionable features, may be used to advantage either by the amateur, or in the factory with a much greater certainty of the pieces coming through with no bare spots, resulting from glaze dropping from the ware during firing.

A 47° Baumé sodium silicate containing:

Na_2O 13.7%
SiO_2 32.9%
H_2O 53.4%

is not appreciably absorbed by a piece of whiteware or faience biscuit having as much as 10% absorption. The molecular formula of such a silicate is:

1.0 Na_2O 2.49 SiO_2 13.54 H_2O Molecular weight 455.1

This may be used as a source of Na_2O and SiO_2 in a glaze of the willemite type without affecting the fusion properties of the glaze.

The glaze may be made in a mortar, in a paint mill or in a ball mill equally well, and grinding does not seem to be necessary for good results. A smooth consistency is all that is necessary for proper application. This may be done by dipping the piece in the glaze or by painting the glaze onto the piece with a brush. After the glaze has dried on the piece it is hard and tough similar to a very thick coating of varnish. It can,

[1] Pukall, *Trans. Amer. Ceram. Soc.*, **10**, 183 (1908).

[2] "Grand Feu Ceramics," 1905, Ceramic Studio Pub. Co., Syracuse, N. Y.

therefore, be handled roughly without any danger of chipping or rubbing any of the glaze from the piece. In the case of tile, the thoroughly dried glazed pieces may be stacked one on top of the other without any danger to the glaze coating.

During firing the water expelled from the silicate causes the surface to be raised somewhat but after this has been expelled, the glaze coat soon settles back into place with no loss of material from the surface.

Such a means of preparation, although theoretically not as thorough in molecular distribution and approach toward chemical equilibrium as in fritting, is nevertheless better than addition of a flux or RO constituent to a raw glaze by way of a granular material.

Procedure

Preliminary work indicated that the base glaze:

$$\left.\begin{matrix} 0.33\ Na_2O \\ 0.67\ ZnO \end{matrix}\right\} \begin{matrix} 1.8\ SiO_2 \\ 0.3\ TiO_2 \end{matrix}$$

was very satisfactory with the coloring oxides whether they were added before or after fritting. It also proved satisfactory with the Na_2O added as sodium silicate. This formula is similar to the Sprechsaal glaze described by Stull[1] and is also covered in the work of Purdy and Krehbiel.[2]

The batch weight of this glaze using the above-described sodium silicate as a source of Na_2O and some of the SiO_2 becomes:

Sodium silicate	150.18	TiO_2	24.00
Flint	58.80	H_2O	15.00[3]
ZnO	54.27		

The colors were added to the above glaze rather than substituted for another RO in the molecular formula. The glaze and color were prepared by milling together for two hours in one gallon laboratory ball mills. They were blended by weight and applied to bisqued faience tiles or biscuit vases with either one or two applications. The latter is most advisable in the case of a vase having somewhat straight sides down which some of the glaze would flow during firing and in which thin glaze coat crystallization is usually retarded.

The same firing behavior as pointed out by most other workers was observed, except that it might be mentioned a somewhat rapid increase in temperature carrying all of the glaze ingredients into solution before

[1] Stull, Discussion, *Trans. Amer. Ceram. Soc.*, **4**, 38 (1902).

[2] Purdy and Krehbiel, *Trans. Amer. Ceram. Soc.*, **9**, 319 (1907).

[3] This is enough to make a good consistency for grinding and application. A larger amount makes the glaze thin and would probably permit absorption of silicate by the porous body of the ware.

the mass has had an opportunity to flow from the piece. This seems to be more important for prolific crystal development than close control of the cooling, and seems to be true for fritted glazes as well as for the sodium silicate glazes.

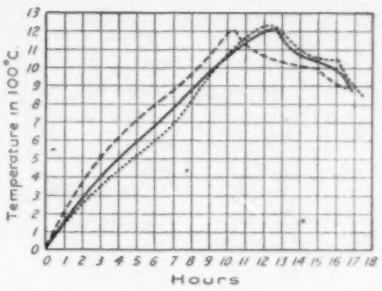

FIG. 1.

Figure 1 shows firing curves which produced good crystallization in a laboratory kiln fired with gas to cone 7 down, under oxidizing conditions.

The tiles were passed through the 93-foot tunnel kiln to cone 9 half down[1] in seventeen hours. In the continuous kiln the tiles were laid flat upon the car top and were exposed to the direct action of the gases through the entire length of the kiln. Oxidizing conditions (4% O_2) prevailed.

The following molecular equivalents of single coloring oxides were added to the glaze with the results indicated.

ONE COLOR SERIES

No.	Molecular equivalents of color added CoO	MnO	CuO	UO_3	NiO	FeO	Cr_2O_3	Four concentrations of each color Crystal	Background
1	0.01							Pale	Creamy
2	.025							Normal blue	Creamy
3	.05							Dark blue	Buff
4	.10							Dark blue	Brown
5		0.01						Fawn	Buff
6		.025						Fawn	Buff
7		.05						Fawn	Brown
8		.10						Dark fawn	Dark brown
9			.01					Very pale green	Pink and cream
10			.025					Delicate pale green	Pink and cream
11			.05					Normal copper green	Pink to tan
12			.10					Dark green	Brown taupe
13				0.01				White or yellow tint	Pale yellow
14				.025				Colorless to creamy	Creamy
15				.05				Pale yellow	Yellow
16				0.10				Pale yellow	Yellow
17					0.01			Pale bluish green	Yellow
18					.025			Pale bluish green	Apple green
19					.05			Apple green	Apple green
20					.10			Few green crystals	Shiny clear green
21						0.01		Colorless	Yellow
22						.025		Colorless	Yellow or buff

[1] See Fig. 2 and *Jour. Amer. Ceram. Soc.*, 5 [6], 267 (1922).

TABLE (*Continued*)

No.	ONE COLOR SERIES Molecular equivalents of color added FeO	Cr_2O_3	Four concentrations of each color Crystal	Background
23	.05		Buff	Brown and buff
24	.10		Buff	Brown
25		0.01	No crystals	Shiny clear green
26		.025	No crystals	Shiny clear green
27		.05	No crystals	Shiny clear green
28		.10	No crystals	Shiny clear green

Using members 2, 6, 10, 14, 18, 22, 26 containing moderate color concentrations, the following mixtures and results were obtained:

Blend	TWO COLOR BLENDS Molecular equivalents of color added CoO	MnO	CuO	UO_2	NiO	FeO	Cr_2O_3	Moderate color concentrations Crystal	Background
2–6	0.012	0.012						Dark blue	Brown
2–10	.012		0.012					Pale blue	Light brown
2–14	.012			0.012				Moderate blue	Creamy
2–18	.012				0.012			Light blue	Yellow
2–22	.012					0.012		Light blue	Light brown or tan
2–26							0.012	No crystals	Shiny clear green
6–10		.012	.012					Pale green	Fawn to pink
6–14		.012		.012				Cream	Fawn to buff
6–18		.012			.012			Bluish green	Cream
6–22		.012				.012		Creamy	Fawn
6–26		.012					.012	No crystals	Bright green
10–14			.012	.012				Pale green	Pink or creamy
10–18			.012		.012			Pale green	Pink
10–22			.012			.012		Pale green	Creamy or fawn
10–26			.012				.012	Mossy, no crystals	Mottled, reddish brown
14–18				.012	.012			Pale greenish yellow	Yellow
14–22				.012		.012		Colorless to creamy	Light yellow
14–26				.012			.012	No crystals	Bright green
18–22					.012	.012		Pale bluish green	Pink to cream
18–26					.012		.012	No crystals, mossy	Shiny apple green
22–26						.012	.012	No crystals	Brownish green

Using members 2, 6, 10, 14, 18, 22 and 26, the following three-color combinations were blended:

Blends	Molecular equivalents of color added							Moderate color concentrations	
	CoO	MnO	CuO	UO_3	NiO	FeO	Cr_2O_3	Crystal	Background
2–6–10	0.008	0.008	0.008					Pale blue	Light buff
2–6–14	.008	.008		0.008				Moderate blue	Buff
2–6–18	.008	.008			0.008			Pale blue	Yellow
2–6–22	.008	.008				0.008		Pale blue	Cream
2–6–26	.008	.008					0.008	Green	Brown
2–10–14	.008		.008	.008				Pale blue	Greenish brown
2–10–18	.008		.008		.008			Pale blue	Pink to creamy
2–10–22	.008		.008			.008		Moderate blue	Buff
2–10–26	.008		.008				.008	Mossy bluish gray	Greenish brown
2–14–18	.008			.008	.008			Pale blue	Yellow
2–14–22	.008			.008		.008		Pale blue	Yellow
2–14–26	.008			.008			.008	Dark green	Shiny apple green
2–18–22	.008				.008	.008		Light blue	Pale yellow
2–18–26	.008				.008		.008	None	Shiny brownish green
2–22–26	.008					.008	.008	None	Bright dark green
6–10–14		.008	.008	.008				Pale green	Pink to brown or buff
6–10–18		.008	.008		.008			Pale green	Pink or buff
6–10–22		.008	.008			.008		Pale green	Pink or buff
6–10–26		.008	.008				.008	Mossy brown	Reddish brown
6–14–18		.008		.008	.008			Pale green	Yellow
6–14–22		.008		.008		.008		Colorless	Creamy yellow
6–14–26		.008		.008			.008	None, mottled	Brown
6–18–22		.008			.008	.008		Bluish green	Brown
6–18–26		.008			.008		.008	Mottled, no crystals	Bright dark green
6–22–26		.008				.008	.008	Mottled, no crystals	Green
10–14–18			.008	.008	.008			Pale green	Pink
10–14–22			.008	.008		.008		Pale green	Pink to gray
10–14–26			.008	.008			.008	Few green crystals	Bright brown
10–18–22			.008		.008	.008		Light blue	Pink
10–18–26			.008		.008		.008	Mossy green or brown	Shiny brown

TABLE (*Continued*)

Blends	Molecular equivalents of color added CuO	UO_3	NiO	FeO	Cr_2O_3	Moderate color concentrations Crystal	Background
10–22–26	.008			.008	.008	Few, brown	Brown
14–18–22		.008	.008	.008		Pale green	Yellow
14–18–26		.008	.008		.008	No crystals	Shiny green
14–22–26		.008		.008	.008	Mottled, green	Shiny green
18–22–26			.008	.008	.008	None	Brown

Using members 4, 8, 12, 16, 20, 24 and 28, two- and three-member combinations constituting a series of strong color concentrations were blended as follows:

Blend	Molecular equivalents of color added CoO	MnO	CuO	UO_3	NiO	FeO	Cr_2O_3	Strong color concentrations Crystal	Background
4–8	0.05	0.05						Dark blue	Dark brown
4–12	.05		0.05					Dark blue	Dark brown
4–16	.05			0.05				Very dark blue	Light brown
4–20	.05				0.05			Dark blue	Greenish brown
4–24	.05					0.05		Dark blue	Dark brown
4–28	.05						0.05	Dark green	Brown underfired
8–12		.05	.05					Normal green	Dark brown taupe
8–16		.05		.05				Fawn	Brown
8–20		.05			.05			Few gray-blue crystals	Dark mottled buff or tan
8–24		.05				.05		Dark fawn or new brown	Brown
8–28		.05					.05	None	Shiny brown
12–16			.05	.05				Dark green	Dark brown taupe
12–20			.05		.05			Mossy gray	Goldstone
12–24			.05			.05		Dark green	Mossy brown
12–28			.05				.05	None	Shiny brown
16–20				.05	.05			Pea green	Green
16–24				.05		.05		Yellow or cream	Brown
16–28				.05			.05	None	Shiny green
20–24					.05	.05		Few, brown taupe	Goldstone
20–28					.05		.05	Brown	Dark brown
24–28						.05	.05	None	Dark brown

THREE COLOR BLENDS

Blend	CoO	MnO	CuO	UO_3	NiO	FeO	Cr_2O_3	Strong color concentrations Crystal	Background
4–8–12	0.033	0.033	0.033					Dark blue	Brown to dark brown
4–8–16	.033	.033		.033				Dark blue	Brown
4–8–20	.033	.033			0.033			Dark blue	Brown
4–8–24	.033	.033				.033		Dark blue	Goldstone
4–8–28	.033	.033					0.033	None	Bubbled (underfired)

TABLE (*Continued*)

Blend	CoO	MnO	Three Color Blends CuO	UO_3	NiO	FeO	Cr_2O_3	Strong color concentrations Crystal	Background
4–12–16	.033		.033	.033				Blue	Buff to brown
4–12–20	.033		.033		.033			Blue	Reddish brown
4–12–24	.033		.033			.033		Blue	Dark green
4–12–28	.033		.033				.033	None	Dark green, bubbled
4–16–20	.033			.033	.033			Blue	Gray
4–16–24	.033			.033		.033		Blue	Brown
4–16–28	.033			.033			.033	None	Green (underfired)
4–20–24	.033				.033	.033		Dark blue	Goldstone
4–20–28	.033				.033		.033	None	Bubbles
4–24–28	.033					.033	.033	None	Bubbles
8–12–16		.033	.033	.033				Pale green	Brown or buff
8–12–20		.033	.033		.033			Pale green	Brown or buff
8–12–24		.033	.033			.033		Green	Mottled taupe
8–12–28		.033	.033				.033	None	Bubbles
8–16–20		.033		.033	.033			Green	Brown
8–16–24		.033		.033		.033		Dark green	Brown
8–16–28		.033		.033			.033	None	Shiny brown
8–20–24		.033			.033	.033		Gray-blue	Mottled buff
8–20–28		.033			.033		.033	None	Bubbled green
8–24–28		.033				.033	.033	None	Brown
12–16–20			.033	.033	.033			Dark green	Reddish brown
12–16–24			.033	.033		.033		Green	Brown
12–16–28			.033	.033			.033	None	Brownish green
12–20–24			.033		.033	.033		Blue-gray	Goldstone
12–20–28			.033		.033		.033	None	Green
12–24–28			.033			.033	.033	None	Brownish green
16–20–24				.033	.033	.033		Olive green	Dark green
16–20–28				.033	.033		.033	None	Bubbles
16–24–28				.033		.033	.033	None	Bubbles
20–24–28					.033	.033	.033	None	Bubbles

Inasmuch as these were blended by weight, a small error is introduced due to the different molecular weights of the coloring materials. This

FIG. 2.—Photograph of loaded car entering tunnel kiln.

per cent is not serious, however, except perhaps in the case of uranium and chromium oxides.

Each member of these two- and three-color series might be represented as the members of triaxials. In this case, however, the triaxials consisting, for instance, of end members 2, 6 and 10 would yield for this study only the binary members 2–6, 2–10 and 6–10, and the one ternary member 2–6–10. A more complete study would, of course, cover more members of such triaxials as well as varying the concentration of color in the end members and interblending strong and moderate color combinations. This, however, becomes a matter of mechanical mixing of glazes.

Conclusions

1. The method of introduction of soda should make these glazes more accessible to many desiring to use them, particularly those who do not have suitable equipment for fritting and grinding these frits.

2. A somewhat rapid increase of temperature from about 1000°C up to the maturing temperature of the glaze seems more important for the development of prolific crystallization than slow cooling.

3. The most interesting development of color in crystals is obtained by blending glazes containing less than 0.05 molecular equivalents of coloring oxides.

4. The most interesting textures are found among the mixtures containing a total color concentration of approximately 0.10 molecular equivalents. These textures are particularly interesting on surfaces where the glaze has an opportunity to spread the color segregations along the vertical sides of the piece. Unusual backgrounds are obtained in this manner.

5. The preferential color absorption by the crystals seems to be in the following order:

(*a*) Cobalt is absorbed in large amount and the color of the crystal deepens to almost a blue-black before the glaze is affected. The brown color of the background is intensified with the cobalt additions.

(*b*) Copper is retained by the glaze with no noticeable amount of volatilization. The green color is totally absorbed by the crystal, but pink in fringes around the crystals and in some portions of the background is prominent when copper is used. This darkens to a reddish brown segregation in a green background when the color goes to 0.10 molecular equivalents.

(*c*) Manganese is not absorbed as much as the cobalt and copper oxides and the color of the background darkens with increase of color.

(*d*) Nickel and iron act very much alike as regards their being absorbed by the crystal except that nickel begins to prevent crystallization at

about 0.05 molecular equivalents, whereas FeO may be added up to 0.2 molecular equivalents, the background darkening in color faster than the crystals, and crystallization not being affected.

(*e*) Uranium is not absorbed appreciably enough by the crystal to be noticeable. Under reducing conditions, black or bronze colored crystals can be obtained with 0.10 equivalents.

(*f*) Chromium cannot be used as a colorant in this glaze. It prevents crystallization even with only 0.01 equivalents addition.

NOTE: The results obtained by the use of these glazes seem to refute the statement that they are ceramic curiosities and commercial impossibilities.

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FURTHER DEVELOPMENT OF AN AUTOMATIC KILN STOKER[1]

By John D. Martin

Introduction

Last year I read a paper concerning the development of an automatic kiln stoker, and stated that at that time we had been engaged in this work for a little over two years. Now, after three years we believe we have this problem well in hand.

We have wanted a dependable machine which we could install on a down-draft periodical kiln, which would feed automatically the same amount of cheap coal into each fire box of the kiln. We have wanted to discharge the ash automatically and do away with any serious clinker troubles on the furnace walls or on the grates. We have wanted to provide at the same time ample mechanical circulation through the kiln for watersmoking and provide forced draft to our fuel bed to burn the coal rapidly. And finally, we have wanted to make an outfit of this character pay a large return on the investment because we have not gone into this merely as a scientific experiment to determine if it is possible to fire clayware with automatic stokers—which fact we settled to our satisfaction three years ago, but our idea has been to determine if good automatic kiln stokers are a good investment for ourselves. If such would prove to be the case, they can no doubt be shown to be a good investment for other manufacturers of clay products who like ourselves, have an equipment of down-draft kilns which they are anxious to keep in operation if they can materially decrease their firing costs. (Periodic kilns have certain advantages from an operative standpoint too well known to all of us to require any explanation here.)

At the time we determined to try a stoker, there was no stoker being manufactured for this purpose, and as far as we could determine there were no industrial stokers being made for any purpose having the small capacity required, which is about 150 lbs. of coal per hour as a maximum. Kiln stoking requires a number of small units operating together and such operation presents the problem of so joining and driving these units that the expansion of the kiln and the stoker setting will not bind or cramp the operation of the individual stokers or their driving mechanism. It is a well-known fact that the average kiln does not stay exactly as it was built; the walls expand and creep outward even in spite of the application of the general run of kiln bands. An important part of the stoker problem is to provide the necessary flexibility of the driving mechanism and the connection of this to the stokers themselves so that any change in the position of the stoker settings is automatically taken care of. In addition

[1] Presented at the Atlantic City Meeting, Feb., 1923 (Heavy Clay Products Division). Recd. Feb. 27, 1924.

to this it is necessary that each stoker should be so connected to the driving mechanism that in case its operation is temporarily interfered with, it can be shut off and the other stokers can continue operation. Rather than attempt to adapt any existing industrial stokers to these conditions, it seemed better to start at the beginning and work out the larger problem thus presented as a whole.

Stoker vs. Coal Feeding Device

Our first stokers were merely a coal feeding device which required the fires to be cleaned by hand at about six-hour intervals. We employed a horizontal pipe which fed fine coal through it by means of an auger to a point underneath the center of a round flat grate from where the coal was fed upward through a vertical pipe by another auger through a hole in the center of the grate. The coal naturally pushed itself outward toward the edges of the grate as the feed continued. The bag wall was set around the edge of the grate about six inches away from it. About half the grate was set in the kiln wall. Coal was fed into the horizontal pipe by gravity from a hopper placed over its outer end. We used a wind box underneath the grate into which the forced draft was supplied and this had to be cleaned out at intervals of siftings which fell through the grate. With this arrangement we were able to secure a very considerable fuel economy when firing face brick, and to cut the time of firing from eight and nine days to about five days.

This arrangement taught us the real difference between an automatic stoker and merely a coal feeding device. We saw that we had accomplished the latter only which took entirely too much labor to operate and that between cleaning periods of a reasonable length, our fires were too dirty to be burning efficiently.

A real automatic stoker is not only a coal feeding device, but it will keep the fuel bed in a uniform condition because it keeps it moving uniformly from the time it enters the furnace as coal, until it is discharged as ash. To keep the fuel bed in this condition is well worth while because the problem is not merely to burn coal in the furnace, but to get the heat from this burning coal circulated through the ware from the top to the bottom of the kiln. A coal feeding device which has first a comparatively thin fire on the grate which thickens and becomes dirty as more and more fuel is fed in, is gradually choking off the circulation through the fuel bed and the kiln. With such a varying condition of the fuel bed, the rate at which it will burn the fuel is constantly changing, as a clean thin fuel bed will burn coal faster and liberate more heat. We were confronted also with the usual objectionable loss of heat experienced when cleaning kiln fires by hand.

Development of the Stoker

After firing a number of kilns of face brick in 1921 with these coal feeders, we determined to change them to real stokers, and our first effort in this direction was to change the shape of the grate from round to rectangular, and to lengthen out the horizontal stoker pipe so that the vertical pipe would discharge up through the inner end of the rectangle, that is, that side of it which was nearest the center of the kiln. The bag wall was built in rectangular shape around the edge of this grate, part of the grate being in the kiln wall as before. Our idea was that the fuel bed would thus be constantly working its way over the grate from the rear toward the furnace door and the ashes would accumulate right inside this door from where they could easily be removed simply by opening the door and taking them out with a shovel. We tried this grate level and also on a slope from the rear toward the furnace door and found that the fuel bed did not move uniformly toward the door in either case. The unburned coal did, but the ashes underneath did not, and this resulted in an accumulation of ashes immediately on top of the grate with a layer of unburned coal over it. These ashes could not be removed without taking out at the same time a considerable amount of unburned coke. We also had a bad accumulation of clinker on the furnace walls.

The reason this idea was not practical is because of the behavior of fine coal during the burning process. When first introduced into a furnace, it will flow readily until the coking process is well on its way, when it will commence to form rather large masses of coke which will not flow so easily. When it has become ash, slightly fused and somewhat cooled, it will flow less readily than either the green coal or the coke, this being especially true if the ash is in contact with the grate. This explains why our fuel bed refused to move uniformly toward the furnace door. Although our grate was very much smaller, our problem was apparently the same as encountered in the design of the largest boiler stokers which have a grate area twenty-five feet square carrying as much as twenty-five tons of coal when in operation.

We therefore designed a rectangular shaped grate with moving members to carry the whole fuel bed toward the furnace door as we did not want to resort to any kind of dumping grate which would fill our wind box with ashes or siftings. After we had all the parts ready to assemble, we discarded this outfit without even trying it out because we decided to go back to the round grate idea as a better means to prevent the formation of clinker on the furnace wall. If we could keep the fuel bed from touching this wall, or at least have it very thin there, we were sure we would have no clinker formation.

We believed we could accomplish this by means of a rotating round grate having the fuel fed to it from the center from below as in our original

layout. In place of a flat grate we have raised it in the center so that it is approximately the shape of a cone. When the kiln is on high fire, the grate is rotated once in about thirty minutes and the ashes are taken off its outer edge continually by a scraper. They fall into the ash pit outside the wind box where they can be reached easily by the fireman with his shovel.

At this time last year we had developed the best means of rotating this grate; we had to discard shafting and gears on account of the warpage of the parts. We had settled on the construction of the grate itself with a rather novel design to give us a large percentage of free opening through it for the passage of the draft and at the same time restrict greatly the falling of siftings through it. We had also found a method of automatically removing such siftings as actually fell into the wind box, and we were fairly successful in preventing clinker formation on the furnace wall without having to resort to special wall construction employed in larger stoker layouts to overcome this trouble.

Refractory Kiln Equipped

We equipped a twenty-eight foot round down-draft kiln with eight of these stokers at a plant making refractories. We have fired this kiln several times with a coal which is of a very different character than the coal used when developing the stoker at New Straitsville. This coal has shown a much greater tendency to form large chunks of coke on the grate and hard clinker on the furnace wall. We have found a means of preventing this coke formation which keeps the fuel bed open to the draft and we are working on the clinker problem with what we believe is a very good chance of success. We found it necessary to remove the clinker once only from about half the furnaces during the five and one-half days of the burn, and while there was some clinker on the walls of the other furnaces, it caused no trouble of any kind and was allowed to remain. The difficulty is no greater in removing these clinkers than is encountered in taking them off the walls of a hand-fired furnace but we wish to avoid any such work of this character about the kiln as our aim is to have the firing labor consist only of shoveling coal into the hoppers and ashes from the ash pit.

We have hand-fired kilns of the same type at this plant on which we have as many as twelve furnaces having a total grate area of about seventy-two square feet. Each stoker has seven square feet of grate area so that the eight stokers on this kiln have but 56 square feet. Yet with this reduced number of furnaces and grate area we have shortened the time of firing from an average of $7^1/_2$ days for the hand-fired kilns to $5^1/_2$ days. In each case a cone 5 was put down located 9 inches above the floor. In firing a kiln set with the same tonnage of standard fire brick shapes I believe we could reduce this time to less than five days because we could watersmoke these quicker than the ware we have been firing which has

consisted largely of locomotive firebox arch shapes some of which weigh considerably over one hundred pounds.

In firing with natural draft hand-fired kilns it is generally the practice to attempt sometime during the burn before the finishing temperature is reached, to stop raising the temperature in the top and soak the heat to the bottom, after which the heat is again raised in the top to the finishing temperature and held until the bottom is finished. To push the top as rapidly as possible to a finishing temperature and pay no attention to the bottom in the meantime, generally results in trouble. Yet this is exactly how we fire this kiln because with a thin hot fire we get a very rapid circulation through the fuel bed and the ware which raises the heat in the bottom very quickly. At the finish of our last firing, which required $5^1/_2$ days, we had a cone 6 down $5^1/_2$ feet above the floor level of the kiln and a cone 5 down 9 inches above the floor.

At no time during the last 18 hours of the firing was the difference in temperature between the top and bottom cone greater than 50°, and some of our readings showed a difference of only 25°. The temperature of the upper cone brick was raised from 1550° to 2150°, its finishing temperature, a difference of 600° in 36 hours, this being at the rate of 400° in 24 hours. You will note that this was not a pyrometer reading taken through the crown of the kiln, but was the actual temperature of the cone brick itself obtained by means of an optical pyrometer. During this time we had high temperatures in the furnaces around 2500°, the highest noted having been 2675°, and it is worthy of note that these were secured with a draft pressure just before entering the windbox as low as .2 of an inch.

Poor Grade of Coal Handled by Stoker

We are burning a grade of coal with these stokers which usually sells for very much less than run-of-mine or lump and which is known in our district as fine coal and is sometimes called slack. In the last few months we have paid as low as eighty-five cents per ton for this coal although recently the price has been advancing. On the other hand we have been paying three dollars per ton for lump coal of a suitable quality for our hand-fired kilns. These prices are f. o. b. the mine. There is very little use for this fine coal except to burn it with automatic stokers, yet the mines have to produce it when loading lump coal and at times it becomes a drug on the market. It is becoming more and more the practice of enterprising buyers to store large quantities of it at such times. Although it contains a considerable amount of dirt our stokers burn it readily. While the augers will not feed through pieces too large to go through an inch ring, they will crush such chunks down to size first and then feed them and I have seen pieces as large as a man's fist disposed of in this way. How-

ever, too many pieces of this size would interfere with the capacity of a stoker as it is primarily a feeding device at the hopper and not a crusher.

Savings Effected

Coal.—The stokers will effect a saving in the cost of firing not only in the amount of fuel required but in its price. The saving in the amount of fuel will depend on whether the previous hand-firing practice has been good, bad or indifferent, and whether mechanical draft has been used or not. The saving in the price of the fuel will of course depend on the coal market, and the maximum amount here will be obvious when it is understood that mine run or lump coal frequently costs two or three times as much as fine coal at the mines. Having recently had the advantage of such a favorable coal market, the saving made on our last burn per thousand brick basis was over $2.00.

Upkeep.—The upkeep of these stokers should be very low as they are a slow motion machine, and there can be a very considerable warpage of the parts carrying the fuel bed before the mechanical action of the stoker would be interfered with. The drive shafting running to each of the stokers turns over at only five or six revolutions per minute when the kiln is in high fire. At the same time the augers are turning at about three revolutions per minute and the grate itself revolves only twice an hour. The grates consist of five separate castings of a very simple construction and they could be very easily and quickly renewed if necessary without the use of any tools—not even a wrench would be required.

Each stoker will require about $^1/_{10}$ h. p. to operate it. The low-draft pressure used means a minimum of power for such service. For the average round kiln I would say that less than 2 k. w. per hour would be ample.

Summary

We can sum up the reasons for expecting economy from our stoker installation as follows:

1. On account of its ability to burn cheap coal.
2. Because of the saving in fuel tonnage due to the burning of the coal under more efficient conditions.
3. Owing to the high furnace temperatures which allow the kiln to be fired off in a shorter time. This means a smaller proportional loss of heat from the stacks and by radiation from the kiln crown and walls.
4. There is no loss of heat such as is usually experienced when fires have to be cleaned.
5. The furnace arches and walls are not subjected to the varying temperatures experienced with hand firing.

6. Owing to the forced draft we are independent of atmospheric conditions and can fire closer to schedule time.

7. We can shorten the turnover of the kilns and get more ware through them.

8. We believe we will decrease the labor cost of firing. Firing with these stokers should not be the hot job which requires the firemen of hand-fired kilns to have so much "time out" which now generally amounts to about thirty minutes out of every hour.

9. Where any flashing of the ware is objectionable, this can be entirely avoided. After the sulphur smoke ceases, there is not even a thin haze of smoke comes from the stack.

10. Circulation through the kiln is so rapid during the watersmoking period, that the danger of the ware in the bottom soaking up moisture, getting soft and kiln marking is reduced to a minimum.

In conclusion I would say that the larger part of our time since we took up this work has been spent in development and not in actually firing ware, but that the good features of stoker firing have nevertheless been so persistent and so marked in the runs we have made, as to be unmistakable in their meaning.

STRAITSVILLE IMPERVIOUS BRICK CO.
NEW STRAITSVILLE, OHIO

Discussion

PROF. WORCESTER: Mr. Martin, have you had any difficulties in holding the top of the kiln from overheating by the steady fire that would be obtained from the stoker, that is, a continuous feed in the stoker? Ordinarily we think that we must have an interval between fires to let a certain amount of air pass through our kiln to drive the excess heat from the top down, but (1) is there any difficulty with the mechanical stoker? (2) Are you able to flash with it?

MR. MARTIN: In answer to your first question, you state that it is generally considered good practice to allow an amount of air to enter the kiln over the fires between firing periods in order to carry the heat away from possibly overheated heads to the bottom of the kiln. We do that because we do not have a steady application of heat at a uniform temperature. Just before the firing period the temperature is low. The kiln is fired and a few minutes afterward the temperature rises to a comparatively high point and it is because the curve is going up that you have to go down. If we have a means of providing a steady application of heat we do not have to go so high with the temperature during the application of heat. Consequently we do not have to go below the average at any time. It is possible to use a temperature from the fire boxes that is much higher than the finishing temperature until the time we are going to do the

finishing. That is, we can subject the ware to a higher temperature as long as it has not reached the maturing temperature, but when the ware commences to reach this temperature naturally we have to cut down the temperature of the gases to about what would be the finishing temperature, so that the ware is not overfired. The fuel bed on the grate of the stoker is very light, and as forced draft is used, we get an unusually rapid circulation through the kiln from top to bottom which heats the ware in the bottom of the kiln very rapidly. It is only after the finishing temperature is reached in the top that we have to stop and wait for the bottom to heat up.

So far as flashing is concerned, we have not tried to do any flashing with the stokers, because they were developed at our face brick plant where we undertook to prevent flashing. That was one of the things we were trying to avoid and why we chose the underfeed type of stoker. This stoker will make a minimum amount of smoke. Whether it is going to be possible to flash ware with this stoker installation or not I am frank to say I do not know.

MR. STEVENS: How much power did it take?

MR. MARTIN: One-tenth of a horse power required for each stoker.

MR. THROPP: How did you take care of the clinker?

MR. MARTIN: In designing the stoker the idea was to take care of the clinker by preventing its formation. We have clinker in two different places, on grates and on furnace walls. With very thin fire and the stoker operated properly the fire will tail so none of the fuel bed will get in contact with the furnace wall. If we have no slag in contact with the furnace, naturally we are going to get no clinker on it. The ashes being taken off from the edge of the grate, the grate will rotate and before it gets around again to the place where we take the ashes off, there will not be enough fuel bed thickness built up against the furnace wall to have any clinker trouble.

As far as the clinker trouble on the grate itself is concerned, that depends pretty largely on the character of the coal you are using. There are some coals that will not clinker badly on the grate. There are some coals that run down on the grate, forming big slabs which shut the air off. There are places where they use oyster shells and limestone mixed in with the fuel in order to prevent that sort of trouble. It does well for a while but it is a difficult matter to contend with.

MR. THROPP: How about the combustion arch that takes care of the gases?

MR. MARTIN: You are acquainted with the ordinary kiln furnace construction. In our case we have a very small furnace. This bag wall gets very warm and aids ignition. The stoker has its grate center under the inside edge of the kiln wall. In the ordinary hand-fired kiln after the ware reaches the ignition temperature of the gases we have the very best

condition possible for good combustion and complete combustion, and under such favorable conditions we can get an impressive idea of one of the failings of hand-firing methods by watching the smoke pour from the stacks after they are fired. When our stoker kiln is on high fire, we do not get even a thin haze of smoke from the stack—it is absolutely smokeless.

MR. HARROP: Mr. Martin, do you use any water or steam to prevent clinker formation?

MR. MARTIN: That is a well-known means to soften up clinkers so they can be easily removed. It does not actually prevent them although it may have some tendency toward that. I do not think I would want to resort to that because there is a certain part of the mechanism below the grate which would rust under the action of steam. While they are cast iron and would not show bad effects from the rust quickly, it is rather doubtful whether that would be good mechanical practice. There is no iron work of any kind above the fuel bed. It would be suicidal to attempt anything of that kind because we would burn it out. We have to keep all the mechanism below the fuel bed and steam and moisture would interfere to some extent, although it might be well to adopt that means if we could get rid of the clinker trouble with it.

MR. BROOKS: Have you considered the possibility of an inexpensive clinker grinder? In the use of underfeed stokers in power plant work one of the principal difficulties has been the problem of removal and ejection of clinker. In selection of stokers very frequently the answer to the question of clinker elimination decides whether an underfeed or chain grate stoker should be installed. Have you considered individual motor drive for each of the various stokers on each of the bags? It would also be interesting to know what percentage of combustible you find comes through the grates with the ash and refuse.

MR. MARTIN: On all the modern later developments of automatic stokers used in boiler practice, they are resorting to clinker grinders but I do not think we are having trouble that would be avoided by the use of the clinker grinder. That is a way of getting rid of the clinker after it is formed. What we are trying to do is to prevent the formation of the clinker in the first place. If I should get the clinker to a place where I would have a clinker grinder, I would find a means of ejecting that clinker without having to resort to a grinder. We have not had any big clinkers formed in the fuel bed. In fact, with a fine coal we generally find a large percentage of dirt that sometimes helps to keep the clinker from forming.

The next point that was brought up was about individual drives. That would be more expensive than the scheme we are using to drive the stoker with shafting. The total power requirement for a kiln as far as the stokers themselves are concerned is one-tenth of a horse power for each

stoker. If we have ten stokers on the kiln, we have only one horse power required. A one and one-half horse power motor would supply that.

MR. BROOKS: Individual motors driving each individual stoker in each bag was what I had in mind.

MR. MARTIN: With the individual motor you would have to have ten small units and they would cost more than the one unit of one and one-half horse power. In other words, you could not buy ten one-tenth horse power motors for what you could buy one one-horse power motor.

MR. BROOKS: The saving would be on operating cost, elimination of line shafting bearings, line shaft friction, and line shaft maintenance.

You mentioned having used wooden shearing pins to relieve the strain in case the feeder mechanism became clogged. These wooden shearing pins have been used for many years in boiler plant practice and have given considerable trouble. Very frequently workmen in replacing a pin do not take the time and trouble of going to the storeroom to get a standard shear pin as supplied by the manufacturer but stick a nail in instead. Motor drive, however, lends itself better to emergency control than engine drive as one can use a circuit breaker with an alarm attachment which immediately indicates to the superintendent when the stoker ceases functioning.

MR. MARTIN: You will always have that sort of thing to contend with. We have it in our plant. For instance, we have a spiral feed under a bin that gets clogged sometimes and we have to have a break arrangement there. A bolt runs through. I go in once in a while and find there are two bolts in there. Some time it is going to break something that is of vastly more importance than a bolt. We have also another feature of the same character in the mechanism that revolves the grate. There is a possible chance some time that clinkers will cause stoppage and so we employ a little link that we saw off the end of an inch and one-half pipe It is about one-sixteenth of an inch thick. It drops down over two pins and in case we have stoppage of the grate for any cause or other that link breaks first and saves breakage of any more important parts. It is a simple matter to find out what the trouble is and drop in another link on there.

MR. JACKSON: As I understand it, it rotates on a vertical axis once in every thirty minutes and the ashes are all scraped off by a scraper only at the front, except what happens to fall down at the back.

MR. MARTIN: There can be nothing fall down at the back. It is all closed except at the front. There is a sixteen-inch slot four inches high above the edge of the grate in front. That is the only place where the ashes can be thrown out except through the door in case of an emergency.

MR. JACKSON: You described a little worm shaft underneath the grate for taking the ashes off.

MR. MARTIN: That is for siftings. As a matter of fact much stuff cannot fall through the grate.

MR. RICE: Have you had an analysis of the ash siftings and do you know what percentage of combustible matter is getting through?

MR. MARTIN: I have not undertaken to convey the impression that this is a finished machine and I have nothing I want to conceal about it. We are getting entirely too much combustible in the ashes and we are taking steps to control that. I have not had an analysis yet but it is entirely too high, and yet even with that condition we are showing a saving of from 20 to 30% in the amount of tonnage required to fire the kiln over hand-firing methods.

MR. RICE: Do you reburn the siftings?

MR. MARTIN: We do not get from one burn from one of these kilns more than two bushel basketfuls of siftings. It would be a very simple matter to do that but here is something that I am going to attempt to do. If I cannot prevent too much combustible in the ashes I am just going to go the other way and force the stoker to throw out a great deal of combustible. It will have the gas practically all worked out of it. I am going to use that stuff again to watersmoke the next kiln. It will be sootless and will make no smoke.

MR. BOLE: How thick does it build up?

MR. MARTIN: The fuel bed should taper off to nothing at the edge of the grate. It would not be over four or five inches at the top. That is a very thin fuel bed and we keep it open on a couple of stokers that we are trying out this way by raising the last two rings at intervals with a very simple mechanism, raising them about an inch and letting them drop. That prevents the formation of coke in masses in the top, breaks open the fuel bed and allows the draft to pass through very easily. We use forced draft pressure just before it enters the wind box of about three-fourths of an inch.

If we use more draft than this on this particular kiln we blow the burning gases out around the edges of the furnace door which we do not consider good practice. We use just enough draft to prevent any suction of air into the furnace around the furnace doors or through the ash outlet, such air as is generally called secondary air which we find we do not need to secure complete combustion.

The forced draft relieves the stack of the frictional load of pulling the combustion air through the fuel bed which will result in a more rapid circulation through the kiln and the stack itself so that the stack will appear to be drawing more freely. While we have not actually increased the pull of the stack, we do increase the circulation through it by having relieved it of part of its load.

FIRING REFRACTORY BRICK IN A ROUND DOWN-DRAFT KILN WITH A MECHANICAL STOKER[1]

By E. E. Ayars

ABSTRACT

An outline of firing tests conducted on round down-draft kilns to develop a mechanical stoker for use in firing fire brick and other refractories. Stoker used has been applied to terra cotta kilns with considerable success but it appears that the larger sizes of kilns are not easily handled with this type of stoker. Further tests may develop something in the way of technique which will show a reduction in firing time. Fuel consumption has already been reduced and uniformly fired ware secured. The time element is of great importance in plant capacity.

Introduction

Mechanical kiln firing methods have been frequently discussed by plant operators, and their adoption when perfected will reduce firing to something like an exact science. In an attempt to secure flexible operation and maximum fuel economy many new types of kilns and special devices have been brought forward from time to time. For certain classes of ware the continuous chamber kiln fired by producer gas or natural gas has proved successful. Oil firing has been adapted to round down-draft and rectangular kilns firing a variety of products. The car-tunnel kiln has been applied to many products and the fuels used include natural gas, producer gas, oil and coal.

New methods are difficult to introduce and often entail great expense. The majority of manufacturers of ceramic products have moved with such caution that comparatively few plants are burning oil or gas, although both of these fuels have their advantages and special fields.

It should be noted that a small percentage of all refractory materials produced are being fired by oil or gas and a still smaller percentage being fired in car-tunnel kilns. Enormous tonnages of fire brick are now fired in both round and rectangular kilns, coal being used for fuel. Irregularities in operation are costing the fire brick maker large amounts of money each year and the results obtained and fuel consumed on some plants would almost cause a graven image to weep. Many fire brick plants in this country are overfiring portions of their kilns and underfiring other portions. The cause of these results is not all in the firing method. Most of it lies in poor kiln construction or design and poor repair while a certain portion is chargeable to indifferent setting.

The special refractory materials such as magnesite, chrome and silica brick are generally fired with more care. This is possibly accounted for by the fact that more attention must be paid to kiln equipment, setting

[1] Presented at the Atlantic City Meeting, Feb., 1923 (Refractories Division). Recd. May 2, 1924.

and firing methods in order to reach the high firing temperatures employed. It is certain that the indifferent treatment afforded refractories fired from cones 4 to 10 would never produce results in firing kilns from cone 16 to 20.

There will continue to be used large numbers of fire brick kilns consuming coal for fuel, but this fuel must be used more economically. It appears that any suitable mechanical method which would permit a closer regulation of fire box conditions would be a paying proposition, and there is a big field for the kiln stoker.

The stokers applied to boiler operation are of several types and generally speaking much too complicated in construction for average brick kiln use. One company has spent considerable money devising a suitable underfeed stoker of the lateral retort type and in a recent article by the designer reports a reasonable success with it. However, it appears that the use of any complicated stoker grate would increase the cost of the equipment unduly and commit the user to large recurrent bills for repairs and parts replacement. A plant operator is loath to adopt any piece of equipment which may give trouble in operation or which may require frequent repairs. The simpler the grate and the operating mechanism the less trouble will be experienced in service and the fewer repairs will be necessary.

The Gates Stoker

The Gates kiln stoker is the result of the development of a mechanical stoking idea. The grates first employed were common flat bars and forced draft was applied. After several unsuccessful attempts to use forced draft, the stoker was tried with natural draft with more encouraging results. Gradually the present grate, consisting of a cast iron plate provided with numerous holes for the admission of air through the fire bed, was developed.

This grate is fixed in an inclined position to facilitate the forward movement of the fuel bed. A slightly smaller flat grate of similar construction is placed between the back wall of the furnace and the end of the inclined grate. Provision is made for withdrawing the flat grate while cleaning fires and the ash and clinker drops through the opening thus effected into the ash pit.

The fuel is held in a small hopper mounted on the stoker frame directly over the feed slide. Power is supplied by a one-quarter horse power motor which drives, through a combination of gears and friction ratchet, the operating device. All feed slides are linked to the driving mechanism by a $^3/_4$-inch pipe circling the kiln. The stoking motion of the slide is slowly accomplished by the action of a cam against a vertical arm to which the circling pipe is attached. At the conclusion of the charging stroke a coil spring pulls the vertical arm back into a notch in the cam thus effecting the back stroke of the feed slide.

The whole mechanism is simple, easily adjusted for different speeds and has a minimum number of wearing parts.

This stoker was developed on terra cotta kilns and up to the present time has shown steady improvement in results. Recently several of the leading terra cotta producers have installed this equipment and are enjoying a considerable saving in attendance, fuel and firing time, at the same time obtaining a high percentage of first class ware.

A Plant Test

The adoption of the fire-box stoker by manufacturers of other products only awaits the satisfactory demonstration of its adaptability to their problem. The designer chose the fire brick industry as the first field for test and made arrangements with the Laclede-Christy Clay Products Company, of St. Louis, to conduct a test at their Laclede plant. This test was observed by representatives of *Brick and Clay Record* who were pledged to publish an unbiased opinion of the results obtained. The report has already appeared but in its present form is hardly available for publication in the *Journal* of this SOCIETY.

In order to obtain data which would permit comparison of common practice and stoker firing a thirty-two foot round down-draft kiln was selected and fired off by the hand method. The kiln was in good physical condition and the setting consisted of sleeves, runners and nine-inch brick. The kiln, of the open bottom type with a continuous bag wall, was equipped with ten fire boxes, each having a grate area of 1,005 square inches. Flat grates were used. The amount of ware set was 164 tons. The average practice of the plant shows a fuel consumption of forty-four tons and a firing time of 132 hours for such a setting. Although the stage had not been set for any records there was a spirit of competition in the air and as might have been expected a record for fuel consumption and firing time was made. The ware was of the usual high quality.

The fuel consumption was 39.34 tons and the firing time 120 hours which shows an all-round efficiency of 111% based on common plant practice. The fuel used was Franklin County, Illinois, run of mine.

It should be noted in passing that the Laclede-Christy Clay Products Company have expended a great deal of effort on their firing practice and have developed their methods to such an extent that they are getting unusually good results in firing time, fuel consumption and quality of ware. The designer of the fire box stoker was fortunate in being able to make his tests on a plant where the standard practice is of such a high order. The head fireman, a man of several years' experience, gave excellent coöperation, and the suspicion with which many new devices are received on a plant was notably absent from the minds of the plant executive force.

As soon as the hand-fired test kiln was drawn the stokers were installed and the kiln reset with similar ware for the stoker trial.

The stoker used was of identical size with that installed on terra cotta kilns, which are usually much smaller and of the muffle type. The grate area of each fire box was 603 square inches or $^{6}/_{10}$ of the original fire-box area. The reduction in area was caused by cutting the width of the grate to eighteen inches. The length remained the same as formerly.

Inasmuch as the stoker operators were not familiar with the open fire kiln it was suggested that a trial firing be run off before the formal test was undertaken. This gave opportunity to study the firing conditions and while the results were not very good with respect to fuel consumption and firing time, the ware drawn from the kiln was first class. The amount of ware set was 201.7 tons. The firing time was twenty hours longer than the accepted standard practice. Fuel consumed was 48.5 tons.

The fuel used was Franklin County, Illinois, screenings which had been in storage on the plant for some months. It was so dirty and low in heat units that its handling presented quite a problem. At the end of the firing it was necessary to break up the lumps in some mine run coal and feed it to boost the heat and flash the brick.

The stoker is used very successfully with screenings from other coal fields but the slaked screenings available for this firing did not measure up to the occasion. The dirt proved a source of trouble and the coking tendencies of the coal caused it to cake on the grates after the first sixty hours. A large proportion of the fuel was thus pushed through the stoker without firing and its heating value lost to the kiln. However, considering the fact of heavy tonnage and tight setting the fuel consumption was not unduly high. The extra time consumed in firing was to be expected in view of the radical change in method and the poor fuel available.

The Second Stoker Trial

The second stoker trial which was observed as a test firing by representatives of *Brick and Clay Record* was of considerable interest. In view of the difficulties in using the dirty screenings on hand a fresh supply of washed screenings was secured from the same coal field. This coal is termed No. 3 and No. 4 nut by the trade and is somewhat cheaper than run-of-mine, but a little more expensive than straight 2-inch screenings. The fuel burned very freely and gave no trouble with coking on the grate. From the writer's experience the coal appeared to burn too freely as it made a flashy fire and the fire box did not seem hot enough to insure the best results at all times. Clinker formed high up on the back wall of the fire box during the later stages of the firing, and while it was somewhat difficult to reach in, cleaning did not affect the fuel bed as clinker formed on the grate would have done. Good combustion obtained at all times

during the firing and the amount of combustible left in the ash was much less than with hand-firing methods. 5.95 tons of ash was left from the hand-fired test and 29.24 tons of coal consumed. 2.5 tons of ash was noted on the stoker-fired test, with 41.53 tons of coal consumed.

The amount of ware set was 165 tons. The coal consumption figured .25 ton per ton of ware while with the hand-fired test the fuel consumption was .24 ton per ton of ware. In this connection it should be noted that the cost of the fuel used on the stoker was $0.95 per ton less than that of the hand-fired burn and shows a distinct saving although the consumption per ton of ware is about equal. The ware drawn from the stoker-fired kiln was equal in every respect to that of the hand-fired test.

In the matter of firing time only does the stoker appear to be at a disadvantage. This is a very important item as it regulates plant capacity and if it were found impossible to reduce the firing time the other possible advantages would not warrant adoption of the stoker. However, let us consider the question of firing time in the light of all the circumstances attending the run, and determine what it promises in the way of future development.

A Discussion of Results

It was apparent at the outset of the firing that the grate area was too small for this type and size of kiln. This had been demonstrated in the first trial firing. The effect of low grate capacity is conceded to be a lengthening of the firing time. Often lack of grate surface may prevent reaching the proper finishing temperature, even though the firing may be continued indefinitely. An increase in grate area was indicated as necessary before further tests were made.

Draft has a decided effect on firing time. The draft available in the hand-fired burn was at all times adequate and, on account of a hot tunnel and stack, abnormally good during the early stages of the firing. In the case of the stoker firing the tunnel was not hot to start with and the draft continued subnormal almost to the end of the firing. It was particularly sluggish up to the 100th hour of the firing when some leaking stack dampers were plastered up and the draft improved at once.

Lack of draft lengthened the watersmoking period materially, requiring sixty-four hours to complete as against forty-six hours for the hand-fired burn. A temperature of 920°F, as recorded by the pyrometer, had been reached in the top of the kiln before the moisture cleared from the bottom. This condition affected the subsequent heat distribution and was largely responsible for the increased length of firing time. Closer study of the causes of sluggish draft early in the firing would have resulted in the same remedial steps being taken and less delay in the completion of watersmoking would have been experienced.

On account of the experimental nature of the test the problem was to determine what method of firing with the stoker would give the results required. At the same time a creditable showing on the quality of ware produced, together with a saving in firing time, fuel consumption and labor was expected. Poor draft and low grate capacity provided a physical handicap, while an unfamiliarity with the firing requirements of the ware contributed almost as much to the lengthening of the burn.

The stoker operators being unfamiliar with the open fire kiln found it necessary to depend absolutely on the head fireman for guidance. He, in turn, being inexperienced with the stoker fire exercised a justifiable restraint over the heat raising speed. The fact that very little air entered over the fire with the stoker, while a considerable excess enters with hand firing, left him sometimes at a loss to know just how to proceed to get a desired result. It is easily seen that with stoker firing the same conditions can be maintained over an indefinite period, while with hand firing there is a recurrent cycle ranging from a very smoky condition when the fire is stoked to a clear bright flame just before the next fire is put on. Just what kind of fire to maintain at different stages of the firing was the real problem.

Considerable time was lost at the finish of the firing on account of a misunderstanding by the stoker operators of what was required. The head fireman was satisfied that the top of the kiln was hot enough and to work the heat to the bottom of the kiln requested a long smoky flame. No further attempt was to be made to raise the heat. This order was placed at 124 hours and it was thought probable that the kiln would come off at 136 hours. However, the flame desired was not carried because of the failure of the operator to understand what was required, and at 136 hours the kiln had not moved. When the head fireman realized how little had been accomplished during the night he explained the requirements further and his wishes were followed closely throughout the rest of the day. The kiln came off fire late that night, fifteen hours after it should have finished according to the calculation of the head fireman. As a result the coal consumption was raised a probable seven or eight tons.

In the light of the foregoing argument it appears that the firing time of the test kiln may be very much improved upon. It should be remembered that hand-firing methods have been in use for many decades and in this particular plant have been brought to a high degree of efficiency. Equal results cannot be expected from the stoker in one or two campaigns. However, taking all the circumstances into consideration the results are remarkable and give much promise for future developments.

CLEVELAND, OHIO

FACTORS AFFECTING THE RESISTANCE OF SILICA REFRACTORIES TO ABRASION[1]

By Fred A. Harvey[2] and Earle N. McGee[3]

ABSTRACT

The resistance to abrasion is tested by grinding a groove in the surface of the refractory by means of a carborundum wheel with suitable mounting. Other methods used in the tests are discussed. Factors affecting resistance of silica brick to abrasion are porosity and degree of burn. Porosity is affected by grind, quality of ganister, per cent lime and workmanship. Data are given showing a rough relation between length of groove, porosity and burn.

Introduction

The abrasion of refractories during service has been receiving more and more attention during the last few years. In this respect it merely follows nearly all the other properties of refractories. The consumer is calling for higher fusion point, greater resistance to spalling, greater resistance to slag action and less shrinkage under load. Many companies are specifying these qualities, using either the methods of the A. S. T. M. or their equivalent. A suitable test for abrasion has been discussed informally in many committee meetings and some preliminary work done toward developing a method. Resistance to abrasion has not been embodied in any specifications with which the writers are familiar except possibly in general terms. It cannot be properly specified until there is some numerical measure of the property. The development of a reliable method will give the manufacturer another control test and aid in the production of a uniformly high grade product. The importance of the subject is evident if we consider a few illustrations, such as the grinding action of the coke on the side walls (see Fig. 4) and floor of a by-product oven during the periodic pushing of the coke and withdrawal of the pusher ram; the abrasion of the walls of a blast furnace and of vertical lime kilns as the charge works its way down; the sand blast action of the gases on hot patches in open hearth furnaces; clinkering of vertical gas retorts and the side walls of stoker fired boiler settings. Many other illustrations could doubtless be added.

M. L. Hartman and J. F. Kobler[4] describe an apparatus for testing resistance to abrasion. Their apparatus consisted essentially of a grinding wheel pressed against the surface to be tested. Speed of rotation, time, and pressure being constant, the amount of material ground away was considered a measure of the resistance to abrasion. The apparatus de-

[1] Presented at the Atlantic City Meeting, Feb., 1924 (Refractories Division). Recd. Oct. 5, 1924.

[2] United States Refractories Corporation, Mount Union, Pa.

[3] Semet-Solvay Company, Syracuse, N. Y.

[4] Kobler, *Trans. Amer. Electrochem. Soc.*, April 8, 1920.

scribed below is similar in some respects to that used by Hartman, the essential difference being that Hartman holds the test specimen against the grinding wheel by a constant force, resulting in a gradually increasing surface being ground away as the wheel penetrates, while in our apparatus a groove of fixed size is ground in the surface of the specimen and after the first few seconds the grinding wheel is always acting on the same amount of surface. Several experiments indicate that Hartman's method is perfectly capable of determining the difference in resistance to abrasion where this difference is large, as for example between carborundum and clay but that it fails to distinguish between two samples of the same class of refractory, such as two silica tile. The method described below has this advantage, that it gives large numerical differences for various tile of the same class.

A third method for testing resistance to abrasion is being tried at one of the large testing laboratories. In this method a sand blast is directed against the surface under test and the amount of material eroded in a given length of time under standard conditions, is compared with the amount eroded from a refractory arbitrarily chosen as a standard. For certain uses this method seems to simulate closely actual operating conditions. It is entirely possible that for these conditions the sand blast method would give the best guide for the production of the most resistant refractory.

All of the tests described below were made on tile at atmospheric temperatures. The assumption is made that approximately the same ratio would hold for both operating temperatures and atmospheric temperatures. It is recognized that this point needs further test though the evidence so far obtained both from laboratory testing of this (cf. Hartman), and other properties and from operating experience indicates that it is not badly in error. It is, of course, much easier to make the tests on cold tile. We have had under consideration for some time a method for making hot abrasion tests and have developed a method so far on paper only. It is hoped to carry out these experiments at a later date.

Description of Apparatus

The apparatus used in the tests described below will be readily understood by reference to Fig. 1. A five-horse power alternating current motor, speed 1800 r.p.m., has a crystolon grinding wheel, 10″ x 1″, mounted directly on its shaft. The wheel is grain thirty, grade "J." Underneath this wheel there is a carriage which moves on tracks parallel to the face of the wheel. The force necessary to move the carriage is supplied in this case by the crude device shown, which consists merely in a bucket attached to the carriage by a window sash cord passing over a pulley. To put the apparatus in operation the brick or tile to be tested is mounted in the carriage at such a height that the wheel will cut a groove exactly one inch deep.

It is then blocked in and clamped tightly by means of the set screws on the side of the carriage. The tracks are wiped clean and the weight in the bucket adjusted until it is just sufficient to overcome the friction of the carriage. A fifteen-pound weight is then added to the weight in the bucket. It consists in this case of the two pieces of angle iron which show in the cut. The wheel is then started and the tile held just out of contact until the second hand of a watch points to 60, when the carriage is released and the wheel allowed to grind a groove in the brick for exactly two minutes. At the end of the two minute interval the carriage is pushed back away from the wheel and the dimensions of the groove measured.

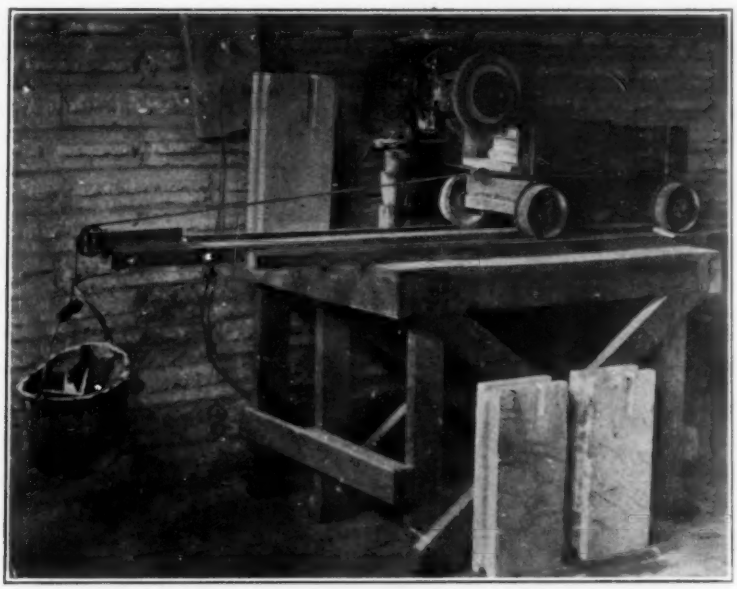

FIG. 1.

The entire credit for this scheme of testing brick for their resistance to abrasion should go to L. D. Huestis of the Portsmouth By-Product Coke Company. Mr. Huestis built the first machine of this type and used it to determine a standard for coke oven shapes.

The apparatus described above has certain defects which can be eliminated by more careful construction. In the first place, the friction is too high. With properly leveled rails and dust proof ball-bearings on the carriage and frequent enough cleaning of rails and carriage, this could be largely eliminated. There is too much side play both in the carriage and the grinding wheel. There is evidence at times that the wheel binds on the side of the groove it is cutting, due to the carriage being out of line,

which undoubtedly decreases the length of the cut. On the other hand if the wheel starts jumping the length of cut may be more than doubled. This effect has been eliminated. It was found that worn bearings, giving the wheel a chance to vibrate in a vertical plane, sometimes resulted in a length of groove all out of proportion to what should logically be expected. For this reason a third bearing, on the outside of the grinding wheel, was added to the apparatus, as shown in Fig. 2. This has resulted in much smoother running and more consistent results.

It has been suggested that the temperature of the wheel has a decided influence on the rate of cutting. This has been tested out in the following way:

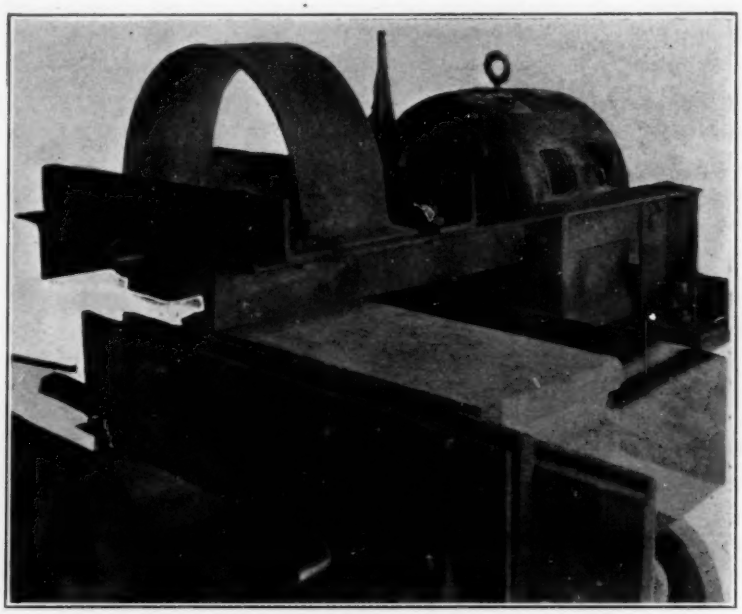

FIG. 2.

A cut was made on a number of tile, allowing the wheel to cool an hour or more between each cut, then cuts made on some of the first tile tested. Usually two cuts made on the same tile check up fairly closely. A second test was run, keeping the wheel in as continuous operation as possible by changing the tile very rapidly. After two hours' run, cuts were again made on the first few tile tested and the length of cut found to be as closely the same as when the wheel was allowed to cool between cuts. It is undoubtedly true that the temperature has a decided effect in the rate of cutting but it seems probable in this case that the surface of the wheel reaches a steady temperature within the first few seconds after starting the cut, so that

continued cutting has very little influence. Tests were also made to determine the effect of dressing the cutting face of the wheel between each cut. With the particular grain and grade of wheel used this again seems to have comparatively slight effect.

After this method for determining the resistance to abrasion had been in use for some time it occurred to one of us that it might be possible to tie up with some other property of the silica brick; particularly with some property which required less elaborate apparatus and possibly one which could be used without destroying the tile tested. This latter idea has not yet been realized but the data given below do seem to show that resistance to abrasion is mainly dependent upon porosity and degree of firing.

The following brief description of methods used may not appear out of place.

Method Used in Determining Porosity

Samples are cut approximately to two-inch cubes, original surface being removed by grinding. The samples are heated, when necessary, to 110°C to remove the moisture and the dry weight (D) obtained to .10 gr. The samples are then placed in kerosene of known density (d) under a vacuum of 24 inches of mercury for four hours at 25°C, and then cooled down to room temperature while yet immersed.

When cool each test specimen is weighed, suspended in kerosene at 25°C to determine its suspended weight (S) in grams.

The saturated weight (W) is obtained immediately after obtaining the suspended weight by drying lightly with a kerosene moistened towel to remove excess kerosene, and then weighing in air.

The porosity (P) is obtained from the following equation:

$$P = \frac{W - D}{W - S}$$

The per cent water absorption (A) may also be obtained from the following equation:

$$A = \frac{W - D}{D \times d}$$

Method Used in Determining Apparent Specific Gravity

Samples are cut to about the size of a walnut, original surface being removed by grinding. The samples are then heated at 110°C to remove the moisture and the dry weight (D) obtained to .005 gr.

The weighed samples are placed in distilled water in a flask to which is attached a reflux condenser cooled by running water. The flask is then subjected to a vacuum of 24 inches of mercury and gradually heated until the water boils. After the samples have been boiled under this vacuum

for one and one-half hours, they are allowed to cool to room temperature while still immersed.

When cool, each test specimen is weighed suspended in water to determine its suspended weight (S) and the temperature of the water is noted in order that its density (d) may be obtained.

The apparent specific gravity (sp. gr.) is obtained from the following equation:

$$\text{Sp. Gr.} = \frac{D}{D - S} d$$

Method Used in Determining Residual Expansion

A half brick of the nine-inch series, or about four inches cut from one end of a shape brick so as to obtain four measuring surfaces, is used. Measurements are made with brick vernier calipers or the volume determined by displacement.

The test pieces are then placed in a gas-fired testing furnace and the temperature gradually increased, following a regular heating schedule, until 1450°C is reached. The temperature is then maintained as nearly constant as possible for seventy-two hours, after which the gas is shut off and the furnace kept closed and allowed to cool. After the furnace is cool the brick are removed and again measured with vernier calipers or by displacement. From the two sets of measurements the per cent change in size is calculated. This change in size, either linear or volumetric, is termed residual expansion.

The residual expansion may also be obtained from the apparent specific gravity data by using the curve developed by the authors.[1]

Some of the results on residual expansion given in this paper were obtained by the latter method because it is more rapid and there were a large number of tests to be made.

Data

Length of Cut

The ability of a silica brick to resist abrasion does not appear to be dependent upon any one characteristic property of the brick but may be influenced by any one or more of the following properties: porosity, degree of burn, grind, quality of ganister, per cent lime, or workmanship (physical structure or bond). Each one of these properties seems to exert an influence, and no single one can be used as an accurate means of judging how a brick will behave when subjected to abrasion. It was found that measuring this resistance to abrasion by the abrasion test machine was the most sure and accurate way of judging this quality. In testing brick from any one manufacturer,

[1] F. A. Harvey and E. N. McGee, "Testing Coke Oven Refractories," *Jour. Amer. Ceram. Soc.*, **4** [6], 474 (1921).

made under the same process, the length of cut appeared, however, to vary fairly consistently with any one property, such as porosity, providing the other properties were approximately constant.

In general it may be said that the average length of cut in silca shape brick suitable for use in coke oven linings was about five inches with two minute grinding. If very hard and dense the cut was less, and if porous,

FIG. 3.

poorly bonded, or underfired, the cut was longer. Fig. 3 shows some tile after testing.

For comparative purposes a few tests were made on fire clay brick. The length of cut in clay brick, with two minutes of grinding, showed 6.6 inches for fairly soft burn, 4.5 inches for hard burn, and 1.4 inches for very hard burn. The following shows a comparison of these results with the porosity of the same brick:

Length of cut, inches	Degree of burn	Per cent porosity
6.6	Fairly soft	24.2
4.5	Hard	19.8
1.4	Very hard	16.9

Relation of Length of Cut to Physical Structure[1]

The approximate behavior of a silica brick in the abrasion test can be determined fairly accurately by visual examination of the physical structure after breaking, and by cutting into it with a small testing hammer having a sharp edge. If the brick is easily cut, or the visual inspection of the structure shows it to be quite loosely bonded, friable, too finely or too coarsely ground, it is quite likely to show a long cut on the abrasion test. Sometimes the skin surface is hard, but the internal structure is soft, consequently a surface inspection is not always adequate. It is

[1] Hammer cut and breaking.

impossible, of course, to draw a sharp line of distinction between brick by inspection, but an inspector can readily tell when the brick are hard and satisfactory or when they are too soft to be resistant to abrasion. If they are doubtful in this quality to resist abrasion, samples should be tested to determine more accurately this quality.

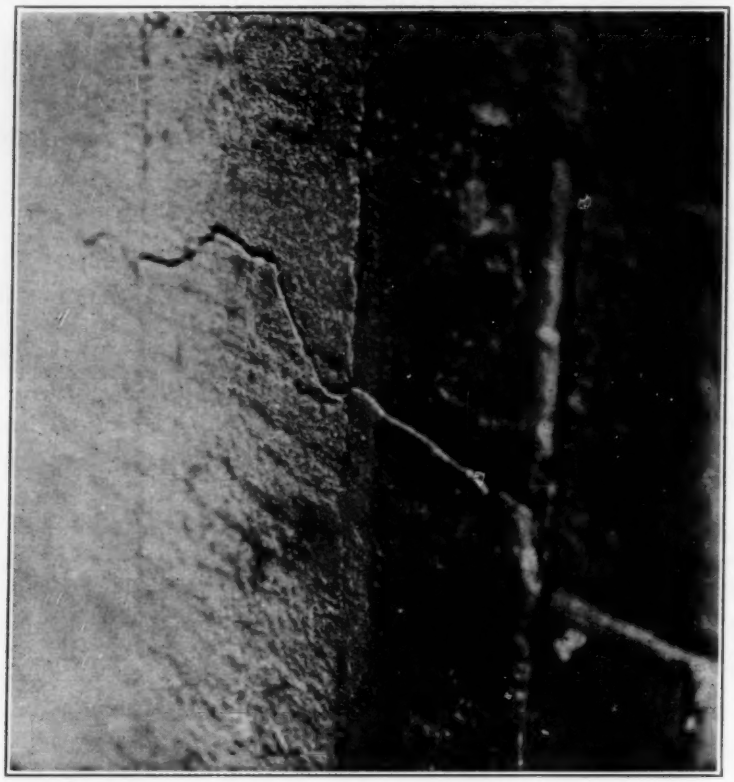

FIG. 4.—Showing abrasion on oven side walls.

Relation of Length of Cut to Porosity

Other properties being approximately the same, the length of cut in silica brick increased with the porosity. A long cut in some cases, in which the porosity was fairly low, could be attributed to the fact that the brick was too coarse or too fine. If too coarse, the grinding wheel had a tendency to pull apart the particles of ganister, instead of grinding through them. If too fine, the material did not seem to offer much resistance to the grinding wheel.

The following results show the relation between the length of cut and porosity and represents a total of approximately one hundred tests The

brick were all made at the same plant, by the same process, and were all hard-fired brick. The various classes (A, B, C, etc.) are grouped according to the length of cut, for two minutes of grinding.

(A) represents the average of all cuts up to 3.5″
(B) between 3.5″ and 4.0″
(C) between 4.0″ and 4.5″
(D) between 4.5″ and 5.0″
(E) between 5.0″ and 5.5″
(F) between 5.5″ and 6.0″
(G) between 6.0″ and 6.5″
(H) all cuts above 6.5″

Class		Average length of cut, inches	Per cent porosity
A	Very hard	3.30	25.23
B	Hard	3.76	26.04
C	Hard	4.35	27.21
D	Fairly hard	4.73	27.64
E	Quite soft	5.24	27.97
F	Soft	5.73	28.21
G	Soft	6.28	28.78
H	Very soft (underfired)	9.74	29.06

(The term hard in this connection refers to resistance to abrasion while soft refers to lack of resistance, not to degree of firing.)

Averaging these results according to porosity instead of length of cut the following data is obtained:

Per cent porosity	Length of cut, inches	Per cent porosity	Length of cut, inches
24.7	3.56	27.8	4.69
25.8	3.81	28.3	5.00
26.3	3.81	28.8	5.59
26.9	4.31	29.1	5.31
27.3	4.25	29.7	5.19

The graph shown in Fig. 5 is obtained from the mass of data represented by these averages. It is not pretended for an instant that it is exact, even its shape may be somewhat in error for the high values. There are so many factors involved that it has been impossible to separate them except in a general way. Particularly at high values the outcome is usually the result of a combination of

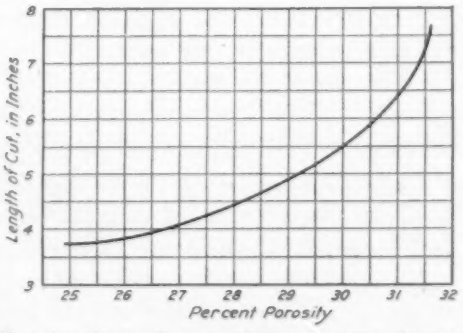

FIG. 5.—Approximate relation between length of cut and porosity.

the causes. We wish to be very emphatic in the caution against taking these values as standards. The results given are for tile made on one plant within a comparatively short period of time, and as such show reasonably consistent results. The change made in the testing apparatus as represented from Fig. 1 to Fig. 2 resulted in a decided decrease in the length of cut on tile apparently alike. Experience with the method extending over two years or more shows that the relation between porosity and length of cut is not absolute, particularly when brick from several plants and from different types of quartzite are under consideration.

The porosity test on one or two brick does not determine definitely how these brick will behave, either in service or on the abrasion test. On a large number of samples, made at the same time and at the same plant, such a relation does appear to exist. Experience has shown, however, that this test alone cannot be relied upon. No brick having a low porosity, 24% to 25%, has ever proved to be soft, but a brick with a porosity of from 28% to 30%, or even higher, may be hard and give satisfactory service.

The more experience we have with testing refractories the more we become convinced of the necessity for taking *all* the tests into consideration in judging of the final result.

Relation of Porosity and Burn to Modulus of Rupture

There is apparently no relationship between the porosity or burn and the modulus of rupture, as is shown by the following results:

	Per cent porosity	Apparent specific gravity	Modulus of rupture, lbs. per sq. in.
1	31.0	2.285	419
2	26.3	2.355	470
3	30.9	2.303	619
4	29.4		630
5	27.7		637
6	26.5	2.307	719
7	30.2		740
8	27.7	2.304	904
9	35.2	2.286	943
10	25.6	2.335	962
11	27.3	2.344	1083

Each of these results is the average of at least three tests on brick which were manufactured by the same process and from the same kind of ganister, and consequently gave very close results on the modulus of rupture test.

No tests were made to determine the relationship between the length of cut on the abrasion test and the modulus of rupture. In some cases, it would seem that they would be comparable, but not in others. The brick numbered (9) for instance, although they showed a high modulus

of rupture, appeared to be soft and easily cut, while the bond was very good. It seemed probable, though, they would not be resistant to abrasion as measured by the abrasion test machine. Also brick labeled (2) looked as though they would be just as resistant to abrasion as brick labeled (7), yet they showed considerably lower results on the modulus of rupture test.

Relation of Length of Cut to Burn

The length of cut also appeared to vary quite consistently with the degree of burn as determined by the apparent specific gravity, or residual expansion. Hard-fired silica brick are usually resistant to abrasion, while underfired brick are soft and show a long cut on the abrasion test.

Class	Length of cut, inches	Apparent density	Per cent residual expansion
A	3.30	2.308	0.35
B	3.76	2.307	0.3
C	4.35	2.310	0.4
D	4.73	2.312	0.45
E	5.24	2.313	0.45
F	5.73	2.311	0.4
G	6.28	2.314	0.5
H	9.74	2.316	0.55
I (underfired brick)	10.30	2.375	1.95

These figures are undoubtedly complicated by other factors.

This test alone, moreover, is not sufficient for judging how resistant a brick is to abrasion. Brick which show a residual expansion of from .5% to 1.0% would be termed hard-fired and yet they may be very susceptible to abrasive action.

Effect of Refiring in Kiln

(A) Length of Cut Refiring silica brick in the kiln increases their resistance to abrasion, as determined by the abrasion machine, between 20% and 30%. A brick which was cut $14^1/_4$" on the original burn showed a cut of $10^1/_4$" after refiring, a decrease of 28%. Brick which were more resistant on the original burn showed a smaller increase in resistance after refiring.

(B) Porosity Refiring silica brick in the kiln decreases the porosity approximately 3%, as shown by the results in the following table.

The greater resistance of a silica brick to abrasion caused by refiring is more likely to be due to the formation of a hard skin surface and stronger bond, than to any appreciable change in porosity.

	Porosity, original brick	Porosity, after refiring	Per cent change in porosity
	30.6	30.7	+0.3
	32.1	31.3	−2.8
	30.1	29.8	−1.0
	26.2	25.1	−4.2
	27.9	28.0	+0.3
	30.3	29.3	−3.3
	32.6	31.3	−4.0
	29.6	28.8	−2.5
	29.3	27.1	−7.5
Average	29.7	28.9	−2.7

Relation of Length of Cut and Ganister

There appeared to be a marked difference between the behavior of brick made from Medina and Baraboo quartzite on the abrasion test. The Baraboo quartzite brick are of such character that they cannot be cut with the grinding wheel used, the material slagging under the heat of the wheel, thus preventing further progress. Some of the western brick which were tested had a very dead, "punky" ring and were of rather coarse texture, yet the length of cut was only one inch in two minutes of grinding. The test machine would undoubtedly have to be changed in some manner in order to make tests on these brick of any value.

Operating Experience

As is shown in the photograph of the coking chamber of a by-product coke oven (Fig. 4) there may be considerable abrasion on the side walls, due to the pushing of the coke, and on some brick this wear is quite marked. It seems to be mostly produced shortly after a new lining is installed. When the brick have been in use for some time, they become more and more resistant to this abrasive action. A careful check on brick put into service show that the abrasion test gives a fair indication of what can be expected of them relative to this abrasive action. Brick of soft structure, which show a cut of 8″ or 10″ in 2 minutes of grinding on the abrasion test, also show considerable wear when put into service, while those which only show a cut of 3″ or 4″ are resistant to abrasion in the oven. The result of this experience with eastern ganister brick would indicate that brick showing a cut of more than 5″ in 2 minutes, or at the rate of $2^1/_2$″ per minute in the particular apparatus used, would be unsatisfactory where abrasive action is important. The method of test has been in constant use for nearly two years and has resulted in the production of tile which are consistently more resistant to abrasion than those previously produced.

Mt. Union, Pa.

ARTIFICIAL SILLIMANITE AS A REFRACTORY.—PART II[1]

By Hewitt Wilson, Clarence E. Sims and Frederic W. Schroeder

Resistance of Refractories to Load at High Temperatures

Of the usual refractories, silica brick bears the distinction of being the only one capable of carrying loads such as those of the roof of the open-hearth steel furnace for continued service above 1500°C.

Silica brick contains a maximum of 6% fluxing material consisting of lime-aluminum silicates, 2% of which has been added as lime to the original quartzite rock. The rest of the impurities are scattered throughout the interiors of the quartzite grains. The lime-alumina-iron silicate flux is so well distributed throughout the silica brick structure and is so small in amount that on fusion, the flux cannot lubricate the adjoining grains, but can only form a liquid medium for solution, saturation, and recrystallization of the silica. In this manner, an interlocking crystalline structure is developed which will resist loads at high temperatures very close to the melting point of the crystalline material.

At the high melting point this crystalline structure disappears and the mass is amorphous. A petrographic examination of a silica brick after failure by shearing at cone 31 revealed no crystalline material.

When the same amount of impurities are added to pure quartz rock as a coating to the grains, the mineral inversions are delayed because of the lack of surface contact with flux and the excess of concentration of fluxes between the grains causes lubrication and early failure. A better method would consist of a very intimate and fine grinding of the flux with a portion of the quartz before adding to the coarse material. An excess of impurities, a low temperature of firing accompanied by an imperfect crystalline bond, or too sudden temperature changes causing the crystalline bond to be broken by rapid volume changes, will all cause early failure.

The permanent expansion of silica brick on heating, which is caused by the inversion of the silica minerals, is peculiar to silica brick alone, for all the other refractories tend to shrink after a certain low temperature temporary expansion period has passed. Fire clay and alumina refractories, manufactured by the usual methods, are composed largely of amorphous materials. The small amount of crystalline kaolinite present dissociates below 1000°C. Other crystalline silicates fuse or are rapidly dissolved by the surrounding fluxes. Crystalline sillimanite will form at the higher temperatures but not in sufficient quantities to provide a rigid crystalline framework. Hence, this amorphous aluminum-silicate mass, possessing no definite melting point but rather a fusion range, deforms at successively lower temperatures as the pressure is increased.

Magnesia and chrome brick with cone-fusion points far above that of

[1] For Part I see *Jour. Amer. Ceram. Soc.*, **7** [11], 842 (1924).

silica brick are notoriously unable to carry load at the high temperatures. Magnesia brick will often contain over 15% and chrome brick over 40% of lime-iron-aluminum silicates, and hence are easily crushed under light loads at the softening temperatures of their silicate impurities. It should be possible to develop an interlocking crystalline structure of periclase or of periclase and magnesio-ferrite if high enough temperatures are used. Very little is known of the high-temperature crystallization of chromite.

The commercial zirconia brick have been bonded with fire clay and naturally follow the load-test curve of the inferior member. Pure zircon, the monosilicate, may possibly be able to develop its own interlocking crystallization.

Refrax brick, made by recrystallizing silicon carbide brick in the electric furnace, is another example of the crystalline-bonded structure which will withstand loads at high temperatures up to the point of dissociation. When clay or amorphous materials are used as a bond, the softening of the brick varies directly with the amount and character of the amorphous bond.

Both the sillimanite and refrax brick of crystalline bond were able to resist the load of twenty-five pounds per square inch at higher temperatures than silica brick and therefore indicate ability to carry the loads required for metallurgical roof work. Resistance to slagging and ability to withstand temperature changes are the other questionable points.

Load-test failure by shear occurs in those brick consisting of a large quantity of more refractory grains or grog, with a small amount of bond which softens first and provides films of lubricant for adjoining grains. By increasing the amount of amorphous material, the failure becomes more gradual and with more preliminary shrinkage before rupture. With large amounts of amorphous material, the brick gradually shrinks to a very small height without cracking.

Spalling Tests

Loss in Weight and Loss in Strength

Both the water-quenched[1] and the air-cooled spalling test methods were used to compare the thermal shock resistance of sillimanite with other refractories. Better and more consistent results were obtained after heating one end of the brick to 1350°C, by cooling in a blast of air from the compressed air line. The brick were weighed after each cooling period and the results tabulated in the following table.

[1] Nesbitt and Bell, *Proc. Am. Soc. Testing Mat.*, **16**, 369 (1916).

R. M. Howe and R. F. Ferguson, "A Study of Spalling," *Jour. Amer. Ceram. Soc.*, **4**, 32 (1921).

R. M. Howe and S. M. Phelps, "The Use of Plastic-Clay Grog in Preventing Spalling," *Jour. Amer. Ceram. Soc.*, **4**, 119 (1921).

TABLE II

SPALLING TESTS

Per Cent Loss in Weight after Air Cooling

Heating	1	2	3	4	5	6	7	8	9	10
Refrax	0	0	0	0	0	0	0	0	0	0
Fire clay	0	0	1	1	1	1	3	3	3	4
Alundum	0	3	7	7	8	51				
Chromite	0	0	0	33	33	33	53			
Sillimanite (stony)	1	3	23	25	26	44				
Zirkite	2	51								
Silica	11	43								
Sillimanite (glassy)	58									
Magnesite	64									

The stony type of sillimanite was superior to the glassy type in both tests and gave better results than zirkite, silica, and magnesia brick of commercial manufacture. The refrax brick developed a series of cracks which were plainly visible when the brick were red hot, but separate portions could not be removed by hand. The fire-clay brick were also resistant to spalling. This sample retained 96% of its original weight after ten treatments. Porous fire brick disintegrate slowly by crumbling; when vitrified, large portions spall off. The alundum and chromite brick were in the intermediate class.

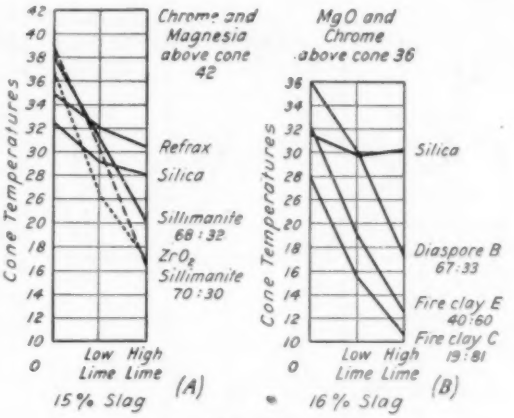

FIG. 10.

(*A*) The fluxing effect of lime as shown by the cone fusion slag tests on artificial sillimanite and other refractories.

(*B*) The fluxing effect of lime on silica, diaspore, and fire-clay brick. (R. M. Howe, "A Study of the Slag Test," *Jour. Amer. Ceram. Soc.*, **6**, 466(1923).)

Resistance to Spalling Determined by Loss in Compressive Strength

The brick were cut in half; one-half was crushed without heating, and the other half heated to 1350°C (cone 14). After holding at this temperature for one hour, it was withdrawn from the furnace and cooled on edge in quiet air for an hour and then replaced in the furnace. The brick were given two heatings and two quick coolings. The preliminary results are given in Table III.

Fire-clay brick unless nearly vitrified at 1350°C retain close to their full strength after two quick heatings and coolings in air. Both the silica and

TABLE III

Sample	No. heatings	Original crushing strength, lbs. per sq. in.	Strength remaining after heating	Notes
No. 2 fire clay	2	2709	72	One sample, nearly vitrified
Woodland fire clay	2	969	102	One sample
Silica	1	1345	0	One sample
Magnesite	1	3051	0	One sample
Refrax	2	5507	73	One sample, split in two halves
Zirkite	2	7363	100	Soap brick, only 2.6″ high. Cracked
Sillimanite-corundum	2	8190	59	One sample. Internal cracks

magnesite brick were total losses after a single quick heating. The refrax brick split in two parts after two heatings but the halves retained 73% of the original strength. The sillimanite brick, depending on the interlocking crystallization for bond, gave the highest crushing strength (8190 pounds per sq. in.) but retained only 59% of this strength after two heatings. However, it showed a better spalling resistance than either the silica or magnesia brick.

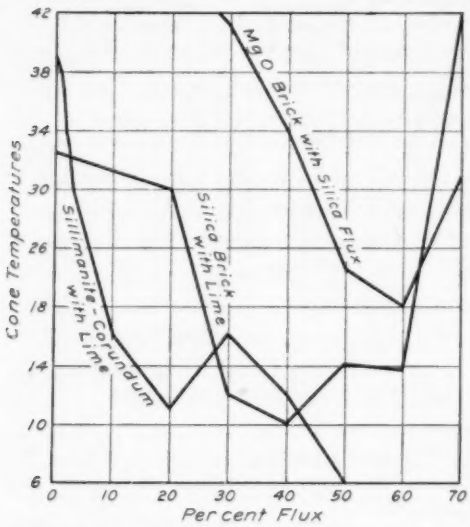

FIG. 11.—Fluxing effect of lime on artificial sillimanite-corundum brick and silica brick. The effect of silica on magnesia brick.

Slag Tests

Cone-fusion Method[1]

This method consists of determining the cone fusion of various mixtures of the refractory and 60-mesh slag. The decrease in cone-fusion temperature from that of the original refractory is taken as a measure of the solvent action of the slag on the refractory. F. W. Schroeder[2] tried the following synthetic slags with sillimanite, and commercial refrax, silica, alundum, and zirkite brick, all ground to pass 100-mesh.

When the results in Table V are plotted against oxygen ratio, silica, alumina, iron oxide, or manganese content of the slags, no definite re-

[1] R. M. Howe, "A Study of the Slag Test," *Jour. Amer. Ceram. Soc.*, **6**, 466 (1923). Also Howe, Phelps, and Ferguson, "The Action of Slag on Silica, Magnesite, Chrome, Diaspore and Fire-Clay Refractories," *Jour. Amer. Ceram. Soc.*, **6**, 589 (1923).

[2] F. W. Schroeder, fellow, Univ. of Wash., in coöperation with U. S. Bureau of Mines, 1922–23.

TABLE IV
COMPOSITION OF SYNTHETIC SLAGS

	1 Blast furnace	2 Heating furnace	3 Open hearth basic	4 Open hearth acid
Silica	38.4	39.5	20.0	50.3
Alumina	13.5	7.1	4.2	5.9
Iron oxide	1.6	50.5	15.6	31.7
Lime	43.0	1.5	47.7	2.3
Magnesia	2.4	0.8	7.0	0.0
Manganese	1.1	0.6	5.5	9.8
	100.0	100.0	100.0	100.0

TABLE V
CONE FUSION OF VARIOUS REFRACTORIES CONTAINING 15% SLAG

Slag No.	0	1	2	3	4
Chromite brick	...	..	...	..	...[a]
Silica brick	32–33	28	28	28	29–30
Zirkite brick	37	16	27	18	26
Alundum brick	39–40	23	27–28	27	27–28
Refrax	35[b]	31[b]	32[b]	30[b]	32[b]
Sillimanite—Melt No. 28	39	18	26	15	35
Sillimanite—Melt No. 41[c]	38	20	29	20	33

a All the chromite mixtures deform above cone 42.
b Indicates rapid dissociation.
c Alumina-silica ratio, 68:32.

lationships are noted. Plotted against the lime content, the curve shows that the activity is the greatest in the slags of high-lime content for all refractories save the chrome and magnesia. This likewise holds true for the sum of the lime and magnesia. As these commercial slags are rather complicated mixtures, comparisons between slags varying but little in lime content show irregularities. The two low-lime slags (Nos. 2 and 4) were therefore combined for one point, and the two high-lime slags (Nos. 1 and 3) for the second point on the curves. (Fig. 10*A*.)

FIG. 12.—Bath slag test No. 1. A portion of the magnesia side walls, and the frozen basic slag containing the softened magnesia brick in the center. The silica brick has been entirely dissolved and the sillimanite-corundum brick standing at the right was pulled from the upper left of the bath at the end of the run.

It is noted that the silica was noticeably less affected by slag than either of the two sillimanite samples. Also, that high lime and low lime caused but little difference with the silica but was a very important factor with the two sillimanite and the zirkite samples. Howe's data[1] given in Fig. 10*B* show similar results in comparing silica brick with the high-aluminous diaspore and two grades of fire-clay brick. It is to be expected from the CaO-Al_2O_3-SiO_2 concentration diagram that mixtures of these three components should fuse at lower temperatures than the lime-silica mixtures. Ternary eutectics are found with melting points as low as 1165° and 1265°C while the binary eutectic between lime and silica is 1436°C.

FIG. 13.—Bath slag test No. 2. Acid slag. The silica and artificial sillimanite-corundum brick, left and right, respectively, have been affected but little, while the magnesia brick in the center has been badly attacked.

Because of the complicated character of the commercial slags and as lime is one of our most active high-temperature fluxes H. C. Fisher[2] made a cone-fusion study of magnesia, silica and sillimanite mixed with lime and a few simple mixtures of lime and silica.

TABLE VI

CONE-FUSION SLAG TEST OF SILLIMANITE WITH LIME

Melt No. 28. Al_2O_3 : SiO_2 : 70 : 30

Per cent lime	0	0.5	1.0	1.5	2.0	2.5	3.0	10.0	20.0	30.0	40.0	50.0
Cone fusion	39	39−	36−	36½	34−	33	30−	16	11	16+	12	6+

TABLE VII

CONE-FUSION SLAG TEST OF SILLIMANITE, MAGNESIA, AND SILICA WITH 20% LIME-SILICA MIXTURES

Slag composition.....	SiO_2	0.0	100.0	75.0	50.0	25	0
	CaO	0.0	0	25	50	75	100
Magnesia brick.....		All above cone 42					
Silica brick.....		32	32	31+	31	30½	30
Sillimanite No. 28.....		39	37+	34	17−	11−	11

TABLE VIII

CONE-FUSION SLAG TEST OF MAGNESIA WITH SILICA

Per cent SiO_2	0	10	20	30	40	50	60	70
Cone fusion	Above cone 42			41–42	34	20–23	18	31

[1] "A Study of the Slag Test," *loc. cit.*

[2] H. C. Fisher, fellow, Univ. of Wash., in coöperation with U. S. Bureau of Mines, 1922–3–4.

TABLE IX

CONE-FUSION SLAG TEST OF SILICA WITH LIME

Per cent lime	0	20	30	40	50	60	70
Cone fusion	32–33	30	12	10	14+	14−	Above 41

TABLE X

CONE-FUSION SLAG TEST OF SILLIMANITE-CORUNDUM WITH Fe_2O_3-CaO IN THE PROPORTION OF $1Fe_2O_3$ TO 1CaO BY WEIGHT. MELT NO. 28

Per cent CaO-Fe_2O_3	0	1.0	2.0	4.0	6.0	8.0	10.0	20.0	30.0
Cone fusion	39	38+	35	30½	19−	15	14	11	6

TABLE XI

CONE-FUSION SLAG TEST OF SILLIMANITE-CORUNDUM WITH Fe_2O_3. MELT NO. 29

Per cent Fe_2O_3	0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	20.0	30.0
Cone fusion	38	37½	36½	35	34−	32½	29	26	20–23	14	10	9

From these seven studies and the accompanying charts (Figs. 10 and 11), it is noted that the fluxing effect of small amounts of lime is greater with sillimanite than with silica. Three per cent lime brought the fusion point of sillimanite from cone 39 to cone 30 and 50% to near cone 6. A rise in the curve at 30 to 40% lime is apparently due to the influence of the gehlenite elevation.[1] Larger amounts of lime reduced the fusion of silica and 40% CaO brought it down to cone10. Or, in other words, with an excess of slag, the fluxing effect of lime should be very similar on both sillimanite and silica brick. Lime had but little effect on the magnesia but 60% silica reduced the cone fusion to cone 18.

FIG. 14.—Bath slag test No. 3. The relative action of the high-lime slag on an artificial sillimanite-corundum brick (right) and the magnesia brick (center). The silica brick was entirely dissolved. At the left is a portion of the slag bath showing how it attacked the magnesia side wall.

Bath Method The cone fusion slag method is an excellent way to determine the effect of the chemical activity of the slag when in intimate contact with the refractory, but in order to determine the resistance offered by the structure of the brick, various refractories were exposed to a bath of slag. The penetration of the slag will depend on the surface exposed, the porosity of the structure, and the fluxing power of the slag on both the large

[1] G. A. Rankin and F. E. Wright, "The Ternary System CaO–Al_2O_3–SiO_2," *Am. Jour. Sci.*, **39**, 40 (1915).

grains and their bonding material. If the bond is easily attacked, the structure is quickly reduced to loose grains. If an intergrowth of crystalline material binds crushed fragments of the same crystalline composition to a dense structure of minimum absorption, the maximum resistance of that material has been found. The resistance of a brick made of crushed fragments bonded with glass depends on the resistance of the glass bond. Amorphous materials should have less resistance than crystalline.

Silica, magnesia, and sillimanite-corundum brick were placed in baths of the following slags:

TABLE XII
COMPOSITION OF SYNTHETIC SLAGS

	1 Basic slag prepared	2 Basic slag open hearth	3 Acid slag prepared
CaO	62.2	44.0	20.0
Silica	15.9	13.2	70.0
Alumina	18.0	4.2	10.0
Fe_2O_3	....	20.9	....
Magnesia	....	9.9	....
Manganese diox.	....	7.8	....
F_2	3.9	....	....
	100.0	100.0	100.0

The slag was placed in 12 x 12 x 9-inch pots of various refractory material in an oil-fired furnace. A series of experiments with temperature variations from 1500°C to 1600°C and time variations from 13 to 24 hours gave the following general results.

TABLE XIII
BATH SLAG TESTS OF SILICA, MAGNESIA, AND SILLIMANITE-CORUNDUM BRICK

Test No. 1. Basic slag No. 1. Total time, 20.5 hrs. Temp. 1550–1570°C for 7.5 hrs. Fig. 12

	Silica	Magnesia	Sillimanite-corundum
Time of failure	16–18.5 hrs.	17–18 hrs.	None
Type of failure	Entirely dissolved	Softened, spalled solution of small pieces	Base eaten
Per cent remainder	0.0%	Not separable from slag	85%

Test No. 2. Acid slag No. 3. Total time, 20.5 hrs. Temp. 1550–1570°C for 7.5 hrs. Fig. 13

Time of failure	....	20.5 hrs.	....
Type of failure	....	Solution, spalling, softening	....
Per cent remainder	100%	93.5% including slag Small pieces	100%

Test No. 3. Basic slag No. 1. Total time, 13 hrs. with slag. Temp. 1475–1530°C for 8 hrs. Fig. 14

Time of failure	7.5 hrs.	13 hrs.	13 hrs.
Type of failure	Complete solution	Softening, spalling solution of small pieces	Bottom eaten until brick fell
Per cent remainder	0.0%	52%	53%

Test No. 4. Open-hearth basic slag No. 2. Total time, 13+ hrs. Temp. 1475–1530°C for five hrs. Fig. 15

Time of failure	7.5 hrs.	11.5 hrs.	Standing at end
Type of failure	Complete solution	Softening, spalling and solution of small pieces	Bottom eaten
Per cent remainder	0.0%	25%, small pieces	80%, one piece

Test No. 7. Iron oxide slag. Maximum temp. 1530–1537°C for two hrs. Hours with slag 9.5, total hrs. 19.5. Fig. 16

	Sillimanite corundum	Zirconia	Silicon carbide
Time of failure	None	8 hrs.	None
Type of failure	Slightly eaten at base	Softened and disintegrated	Eaten badly at base
Per cent remainder	95%	50%	95%–

1. As shown in Table XIII, a silica brick standing on end in a 4-inch bath of both basic slags entirely dissolved before the magnesia brick softened or spalled enough to give way or the sillimanite-corundum brick had its base eaten. (Figs. 12, 14, and 15.)

2. In the acid slag both the silica and sillimanite-corundum brick were far superior to the basic magnesia brick. (Fig. 13.) In all these tests the magnesia brick have had a handicap of spalling with the quick heating and in this way the surface exposed to the slag has been increased. Nevertheless, when standing on end and heated on all sides with no slag present, the magnesia brick will slump and split longitudinally above cone 30 under their own weight, showing that the silicate bond will not stand the high temperatures. As magnesia is not affected materially at these temperatures by the action of lime, the disintegration of the magnesia brick in slag is undoubtedly caused by the fusion of its silicate bond together with the low resistance of the latter to the slag.

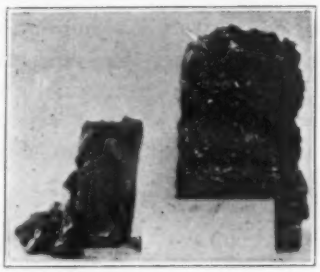

FIG. 15.—Open-hearth basic slag test No. 4. The silica brick was entirely dissolved while 80% of the artificial sillimanite-corundum brick (right) and only 25% of the broken magnesia brick remain.

3. The artificial sillimanite-corundum brick are able to maintain their rigidity under load at high temperatures even better than the silica brick and have less internal pore space for slag penetration, together with a moderate resistance to spalling, which, while it is not as good as some of the other refractories, is distinctly better than the silica or magnesia brick. Hence, although lime attacks both the silica and sillimanite readily, as shown by the cone-fusion slag tests, sillimanite-corundum brick were produced with a far better structure and less exposed surface which enabled the latter to lose only 25% while the silica brick lost 100% weight in a lime slag bath.

FIG. 16.—Iron-oxide slag test No. 7. Sillimanite, left; zirconia, center; and silicon carbide, right.

Several service tests have been made in the walls of a basic open-hearth steel furnace and in the roof of an electric iron furnace. In these positions a few sillimanite-corundum brick of laboratory manufacture have been surrounded with commercial silica brick. Both good and poor comparative results have been obtained. The chief difficulty was found in the spalling of the dense sillimanite-corundum structure in the repeated heatings and coolings, especially after the silica brick had receded and left the sillimanite-corundum brick projecting with five faces exposed. It is difficult to produce enough of these brick with laboratory apparatus for a large-size test and also to prevent the tendency towards brittleness in the fast cooling of the small kilns.

TABLE XIV

POROSITY OF VARIOUS REFRACTORIES

Refractory	Per cent absorption by weight	Per cent apparent porosity by volume
Carbofrax	5.2	12.2
Sillimanite-corundum	7.3	17.1
Silica	13.0	23.4
Zirconia	6.8	25.0
Chrome	13.4	25.6
Spinel	10.1	25.7
Average fire clay	15.1 (11.4–20.6)	28.1 (22.0–34.8)
Magnesite	14.3	32.9
Refrax	19.4	35.8

Summary

The results from the laboratory tests would indicate:

1. Sillimanite-corundum brick will withstand higher direct temperatures than the present silica, magnesia, chrome, fire clay, and zirconia brick.

2. Brick made from sillimanite-corundum mixtures, having the interlocking recrystallized structure will resist load at high temperatures better than any of the common refractories except refrax and better than the sillimanite-glass brick.

3. Though hard and dense, they will resist spalling better than silica and magnesia brick but are distinctly inferior to the ordinary fire-clay brick in this respect. A more open porous structure may be developed for conditions where resistance to spalling is essential and a high resistance to load at high temperatures is not essential.

4. Sillimanite-corundum brick will resist acid slags. While attacked by basic slags badly in the cone-fusion slag test, the brick structure can be made so dense that a greater resistance is produced than that of the open porous silica brick.

5. When lime as an impurity in sillimanite exceeds 1.5% it becomes a serious factor in reducing the fusion temperatures.

NOTE: We wish to acknowledge the kind assistance of the following co-workers: Clyde E. Williams, superintendent of the Northwest Experiment Station, U. S. Bureau of Mines, for general supervision and advice; E. P. Barrett, J. D. Sullivan, and A. E. Anderson of the Northwest Experiment Station, U. S. Bureau of Mines, for chemical analyses, and G. E. Goodspeed, of the University of Washington for petrographic examinations. A. L. Bennett, formerly fellow, University of Washington, also did considerable preliminary work in the preparation of sillimanite refractories.

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Discussion

MR. GREAVES-WALKER: In attempting to find the silica-alumina ratio which would produce refractories having the best physical qualities, from a diaspore, we ran the gauntlet of raw materials having alumina contents ranging from 50% to 85%. We found invariably, that when we used a single material or a mixture that would produce a finished product containing approximately 63% Al_2O_3, we got the best combination of physical properties it was possible to obtain from a high alumina refractory. There would seem to be no question, therefore, that the sillimanite ratio produces a very superior product.

MR. PHELPS: Will Prof. Wilson elaborate a little bit on his method of forming that material, that is, the method of making the brick and also the method of preparing the material: whether the materials were ground or not, etc.

PROF. WILSON: This material is the result of electric fusing. We started out by using commercial materials, but in order to tie the thing down to pure product we used English china clay corresponding as closely as we could get it, and purified aluminum oxide, using various mixtures of this china clay and aluminum oxide. Cone 16 is the point at which most refractories start failing under load if they have present a certain amount of quartz glass. In producing any of these electrically fused products it will be necessary to have enough of some other oxide present to take up all of the silica in order to get a good product.

DR. PRATT: Did you use any of the natural mineral sillimanite?

PROF. WILSON: No.

DR. PRATT: In your resultant product you stated that there are crystals nearly an inch long. Did you analyze them to see whether they were sillimanite?

PROF. WILSON: Dr. Bowen, a few months ago, analyzed crystals in order to get as pure a crystal as possible and he found that such materials corresponded very closely to that given for sillimanite.

DR. PRATT: If I understood it correctly you stated you got the best results when you had sufficient alumina in your mass so that the resulting mass showed not only this mineral but also the crystals of corundum.

PROF. WILSON: If somebody can give an explanation of why that small amount of crystals will cause the crystallization of the sillimanite into the mica crystal form, he will be rewarded. We have explained it by the fact that possibly it is because the sillimanite crystals start growing, the plate of corundum comes out on top and prevents a growth.

DR. PRATT: Did the corundum crystallize out first?

PROF. WILSON: No, I think not. The only evidence we had was that on top of the tiny sillimanite crystals was a plate or film. A great many crystals of sillimanite had a plate of corundum riding on top.

ERRATA

W. E. Rice and R. A. Sherman, "Determination of the Distribution of Heat in Kilns Firing Clay Wares," 7[10] 748 and 749 the formulas should read:

$$H = 1543\left[\left(\frac{t_2 + 460}{1000}\right)^4 - \left(\frac{t_1 + 460}{1000}\right)^4\right]$$

instead of $H = 1543\left[\frac{(t_2 + 460)^4}{1000} - \frac{(t_1 + 460)^4}{1000}\right]$.

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Abrasives

Manufacturing an artificial abrasive. ANON. *Chem. Met. Eng.*, **31**, 501–3(1924).—The manuf. of carborundum is described. Coke, sand, salt and sawdust are charged into a U-shaped elec. fur. A core of graphite through the center of the charge carries the current. After 36 hrs. the charge is cooled and sorted. There is a top crust of unconverted charge, an intermediate layer of partly converted mix. known as firesand,

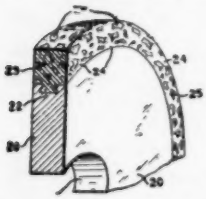
[1] The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

and inside, the pure carborundum. The large chunks of carborundum are crushed in pan crushers, digested with acid to remove harmful ingredients, washed, dried, and sized into 21 grades. M. E. M.

Making vitrified abrasive wheels. ANON. *Chem. Met. Eng.*, **31**, 531–3(1924).—Describes the manuf. of carborundum grinding wheels. Two methods are used: wet process and dry press. In the latter, the carborundum particles are tumbled in barrels with the bonding mat. for several hours. Water is then added till the mix has the consistency of molding sand. The wheels are pressed in steel molds by hydraulic presses and dried for several days before firing. In the wet process, the mats. are mixed with water to a thin paste, stirring for many hours. The stirrer is designed to eliminate admixture of air bubbles. The mix is transferred to metal molds lined with heavy paper, and worked by hand to eliminate air bubbles, then dried. The wheels are fired in down-draft, coal fired kilns in fire clay saggers. The firing cycle is 2 weeks. The fired wheels must next be dressed to size, and balanced before their final inspection. M. E. M.

Manufacture of artificial abrasives in the electric furnace. C. J. BROCKBANK. *Birmingham Metallurgical Soc. Jour.*, **7**, 551–9(1924).—This article discusses the early history, manuf. and finishing of silicon carbide; aluminous abrasives or artificial corundum and manufacturing costs. It is illustrated and contains tables of analyses. O. P. R. O.

PATENT



Polishing wheel. CLARENCE R. KING. U. S. 1,507,836, Sept. 9, 1924. An abrasive article comprising a resilient cushioning body and spaced teeth of bonded abrasive grains united therewith.

Art

Color measurement with Lambert's mirror. HEINRICH TRILLICH. *Farben-Ztg.*, **28**, 1601–2(1923).—A very brief biography of Johann Heinrich Lambert (1728–1777), with a description of his mirror, which consists of a plane parallel glass plate set vertically across the center of a horizontal plate equally illuminated on all parts. Colored cards placed on the horizontal plate on opposite sides of the plane parallel glass will show varying degrees of transmission and reflection depending on the angle of observation of the glass. Expts. with this mirror on some of the colors making up Ostwald's color circles, show that it can be used for demonstrating color mixing, complementary colors, etc., and for the measurement of colors. F. A. W. (*C. A.*)

PATENT

Manufacture of cement, burned lime, etc., in electric furnace. T. A. F. HOLMGREN. Swed. 50,536, Jan. 4, 1922. The raw materials are crushed into suitable grain sizes, mixed and fed into an elec. furnace. The heat is produced in one or more zones by a. c. which is applied through one or more circuits with phase-differences like 360° divided by the no. of circuits. Gas is drawn or forced through the furnace in opposite direction of the materials. (*C. A.*)

Cement, Lime and Plaster

How silica cement is made. P. H. JUNG. *Chem. Met. Eng.*, **31**, 465–7(1924).—Silica cement is used for laying silica brick. It is made from crushed silica bats and a high quality plastic clay in the ratio of about three to one. Crushed ganister is sometimes added, but is unnecessary. The clay used must be low in iron and alkalis. A typical anal. is given. The raw mat. may be crushed sep., then mixed and ground, or mixed, then crushed and ground. The 1st method is preferable. The mixt. is generally ground in ring roll pulverizers, and screened on inclined screens. If too fine a screen

is used, there is a tendency for the silica and clay to sep. The 3 most important tests for the finished product are fineness, fusion point and plasticity. M. E. M.

Concrete factory chimneys. *S. African Jour. of Indus.*, **7**, 503(1924).—A new method of constructing factory chimneys in concrete depends on the use of hard burnt tile and steel reinforcement in the shape of vertical bars and horizontal rings. The tile form the inner and outer walls and serve as permanent molds for the concrete. Being of comparatively small size, the tile also ensure that the concrete is placed carefully in small quantities, while the steel reinforcement gives resist. to wind-pressure and to cracking through temp. changes. In bldg. a chimney in accordance with this method, the foundation is put in with requisite reinforcement of vertical bars extending upwards, and an inner and outer ring of tile are set in mortar. The annular space is then partly filled with concrete, the circular reinforcement rings placed in position, and the filling continued level with the tile. Another row of tile is then laid as before, and the process continued, each course breaking joint with the next, and the joints being afterwards pointed in the same way as brickwork. It is claimed that with careful workmanship this method will produce a sound structure which is safe and durable, calling for the minimum of repairs and giving the max. of economy and permanence. (*London, Times Eng. Supp.*) O. P. R. O.

Sand-lime brick process. ANON. *Indus. Australian and Min. Stand.*, **72**, 296 (1924).—The value of sand-lime brick is equally proved by means of chem., mech. and phys. tests. Thus they have greater resist. to crushing strain than ordinary brick, and are less absorbent to water, while possessing equal porosity to the air. All are perfectly straight and of equal size, there being no twisting, bulging, or distortion, so that less mortar is required to lay them, and it is easier to obtain efficient results with plaster because of the smooth surface given. The process of manuf. is simple and can be carried out with unskilled labor. Mix sand intimately with 5 to 10% of thoroughly slaked lime, forming this into a semi-dry mass with water, passing it through a brick molding mach. operg. at 2 T. per sq. in. press., and then ht. for 10 hrs. in closed cylinders at a temp. of approx. 350°F under a steam press. of about 120 lbs. per sq. in. Under these circumstances a chem. reaction takes place between part of the silica and the lime, resulting in the formation of hydrated calcium silicates, which bind the whole mass together, forming an intensely hard, close-grained and homogeneous brick which somewhat resembles stone. The entire process can be completed, from raw mat. to finished brick in 24 to 36 hrs. in striking contrast to the many months of aging necessary in case of ordinary fired clay brick; the sand-lime method is in general cheaper, and has the advantage that sand occurs almost everywhere, while suitable clay does not. The lime should not contain the slightest trace of unslaked lime lest the brick expand, become distorted, weak and friable. If the lime is properly slaked, sand-lime brick is unquestionably superior to ordinary brick. O. P. R. O.

Cement manufacture possibilities in crown colonies. ANON. *Bull. of Imp. Inst.*, **22**, 173–93(1924).—The possibilities for cement manuf. in many Brit. possessions and the importance of utilizing local supplies has been investigated. For this purpose a lab. has been established with plant necessary for (1) the mech. prepn. of large samples of raw cement mat., (2) the carrying out of exptl. firing trials, and (3) the testing of the finished cement in order to ascertain whether it conforms to the standard specif. The article gives an outline of the manuf. and properties of different kinds of cement, special attention being devoted to the charac. required in raw mat. for the several classes of cement used in building. This is followed by particulars relating to the possibilities of cement manuf. in the various Colonies and Protectorates and an acct. is given of the deposits so far known and the results of tests conducted at the Imp. Inst. lab.

O P. R. O.

Contribution to the knowledge of the hydration process in the setting of Portland cement and of clinker. HANS PULFRICH AND G. LINCK. *Kolloid-Z.*, **34,** 117–9(1924).—Previous observers working with a large excess of H_2O have noticed during the setting of cement the formation of needles of a Ca silicate, then hexagonal plates of Ca aluminate, and finally the disappearance of the crystals with formation of a gel. In the hydration of clinker the hexagonal plates appear first, then the gel and crystals of $Ca(OH)_2$. The hexagonal plates were made synthetically by melting together $3CaO$ and Al_2O_3 and treating with H_2O. The crystals proved to be $3CaO.Al_2O_3.7H_2O$. The needles were also synthesized by making the tricalcium silicate by melting together $CaCO_3$ and SiO_2 and treating with H_2O. They can also be prepd. by treating a 5% SiO_2 soln. with $Ca(OH)_2$ soln., warming on the water bath and letting stand for a week. On prolonged standing both types of crystals decompose again to form a gel. When the amt. of H_2O added to the cement is cut down more nearly to the proportion used in practice by employing mixts. of glycerol and H_2O in place of H_2O alone for making the microscope slides it is found that the setting of the cement takes place without the formation of the needles, the reaction proceeding at once to the gel stage. It is, therefore, concluded that the hardening of cement is due to the formation of the gel rather than to the interlocking of the needle-like crystals. F. L. B. (*C. A.*)

The Segni (Rome) cement plant. F. FERRARI. *Cemento* **20,** 101–5(1923); *Chimie et industrie*, **11,** 1140(1924).—A description of the plant. A. P.-C. (*C. A.*)

Enamel

Principles of enameling. I. H. F. STALEY. *The Ceramist*, **4,** 6(1924).—The 1st of a series of articles for the special benefit of the man who has not had tech. training. The methods of calcg. melted wt. and percentage loss on melting, and coeff. of expansion without the use of chem. symbols are shown. C. W. P.

PATENTS

Production of a non-chipping enamel. R. MADES. Ger. Pat. 396,752, Dec. 29, 1922. (*Jour. Soc. Chem. Ind.*, **43B,** 788(1924).) The ground coat is applied in so dilute a condition that after firing it is invisible to the naked eye. Thus the finished ware can be subjected to very considerable shocks and blows. H. H. S.

Enamel paint. F. SCHAMBERGER. Ger. 376,569, *Oil & Color Trade Jour.*, **66,** 1052(1924). The sap of the shells of the oil-fruit seeds of Anacardium occidentale or A. orientale, or a mixt. of both, is used, with or without addn. of drying, binding, and hardening agents. O. P. R. O.

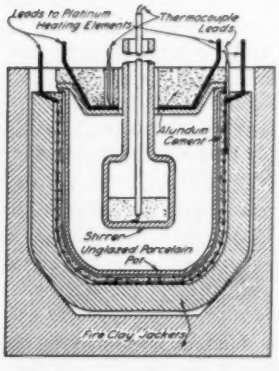


FIG. 1.—Diagram showing arrangement of parts of viscosimeter, heating circuits, and thermocouples.

Glass

The viscosities and surface tensions of the soda-lime-silica glasses at high temperatures. Part I. Viscosities of glasses at high temperatures. EDWARD W. WASHBURN AND GEORGE REED SHELTON. Univ. Ill. Eng. Expt. Station, *Bull.* **140,** April 14, p. 8–50 (1924).—*Method.* The method adopted was that of rotating cylinders, the glass being contained in an approx. cylindrical porcelain pot into which was dipped a hollow porcelain stirring cylinder. The latter was rotated at a measured speed by means of a system of falling wts. For a given apparatus employing a const. height of liquid, the simplified equation (2) holds

$\eta = k\frac{W}{S}$, where η is viscosity of the liquid, W the mass of the falling wt. which rotates the inner cylinder in the glass at S r.p.m., and k a const. of the apparatus which is detd. by calibration with liquids of known viscosity. *Standardizing liquids.* A series of glasses were prepared by mixing in proper proportions: water, dextrose and confectioner's glucose. A wide range of viscosities were thus obtained. The viscosities of these liquids were detd. by (1) the capillary-flow method, using viscosimeters of the Ostwald type, (2) the falling sphere method, using nickel-chromium steel balls and small drops of mercury, and (3) Washburn's capillary-penetration method. The compns. and viscosities of the standardizing liquids are given in Table 10.

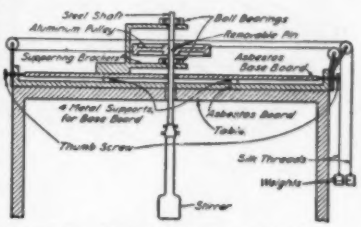


FIG. 2.—The driving mechanism.

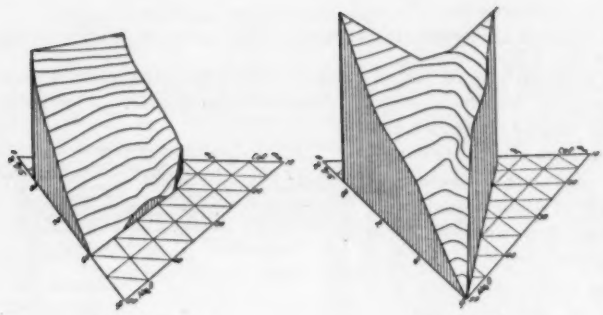
TABLE 10

SUMMARY OF VISCOSITIES OF VISCOUS LIQUIDS

Values in parentheses are taken from the literature

No.	Description of solution	Temp., deg. C	Capillary methods η	Capillary methods log η	Falling-sphere method η	Falling-sphere method log η	Value from curve of Fig. 7 η	Value from curve of Fig. 7 log η
1	60% Sucrose	24	(0.4638)	(−0.6663)	...	...	...	...
2	60% Sucrose	0.3	(2.330)	(0.3674)	...	...	...	...
3	80% Glucose				3.442	0.5369		
	$d^{25°}/_{25°}$ = 1.331	25	3.696	0.5677	3.388	0.5299	3.43	0.535
					3.531	0.5479		
					4.186	0.6218		
4	Castor oil	24.8	(6.62)	(0.821)	...	...	...	...
5	Castor oil	21.75	(8.50)	(0.930)	...	...	...	...
6	90% Glucose				35.99	1.5562		
	$d^{25°}/_{25°}$ = 1.379	25	36.62	1.5637	35.29	1.5477	36.6	1.562
					35.50	1.5502		
7	98% Glucose				749.3	2.8747		
	$d^{25°}/_{25°}$ = 1.420	25	...	...	743.5	2.8713	764	2.883
					772.0	2.8876		
8	100% Glucose				5 699	3.7558		
	$d^{25°}/_{25°}$ = 1.436	25	...	...	5 314	3.7254	3 000	3.475
					5 287	3.7232		
9	Glucose and Dextrose	19	13 620	4.1342	13 460	4.1291		
					13 440	4.1284	16 600	4.220
	$d^{25°}/_{25°}$ = 1.447				13 870	4.1418		
10	Glucose and Dextrose				163 300	5.2130		
					163 300	5.2130		
	$d^{25°}/_{25°}$ = 1.470	18.9	165 900	5.2199	165 000	5.2175	163 000	5.212
					167 600	5.2243		

The viscosities are given in *poises*, the poise being the tangential force per sq. cm. of area of either of two horizontal planes one cm. apart, one of which is fixed, while the other moves with unit velocity, the space being filled with the viscous liquid of unit viscosity. *Variation of the constant k in equation* (2) *with the viscosity of the liquid.* A brass app. was used consisting of two concentric hollow brass cylinders, the inner cylinder rotating within the outer one on bearings. The space between was filled with



(1500°C.) (1000°C.)

FIG. 10.—Models of the log η surface.

the liquid, and the const. k of the apparatus was detd. from the velocity attained by the inner cylinder, actuated by falling wts. From the results it is concluded that regardless of the viscosity of the liquid employed, the rate of shearing is directly proportional to the torque, but that the stirring friction viscosity as measured by the rotating-cylinder method is identical with the viscosity as measured by capillary or by falling-sphere methods, only as long as the viscosity does not exceed a certain value, possibly depending upon the dimensions of the rotating-cylinder apparatus. The value of k varied from 70 to 353, depending on the viscosity of the liquid. The caution is added that in measuring the viscosities of very viscous liquids by the rotating-cylinder method it is advisable to standardize the apparatus with a series of liquids of known viscosities, covering the range desired.

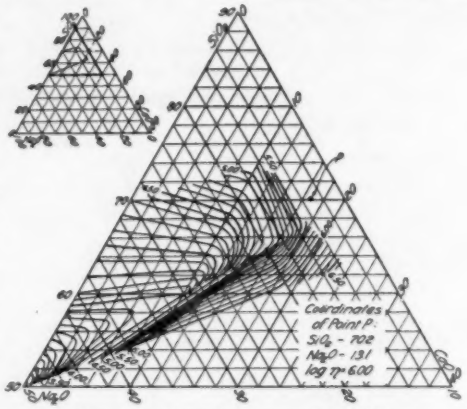


FIG. 12.—Log isokoms at 900°C.

Calibration of porcelain pots and stirrers. For each standardizing liquid, placed in a porcelain pot with stirrer in position, the straight line relationship between different falling wts. and the corresponding r.p.m. values were determined. The logarithms of the values of the slopes W/r.p.m. were plotted against the logarithms of the corresponding viscosities of the standardizing liquids. By detg. the values of W/r.p.m. for any unknown liquid, the viscosities can then be obtained from the curve.

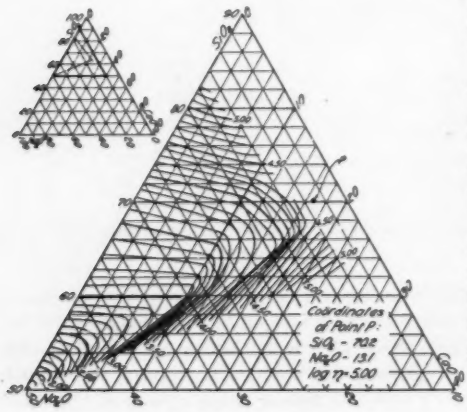


FIG. 13.—Log isokoms at 1000°C.

Viscosities of the soda-lime-silica glasses. By mixing three stock glasses of known compn. the following glasses were obtained, and investigated (Table 15). Chem. analyses of the stock glasses and of two mixtures indicated the slight variations in compn. due to melting. All the glasses contained small quantities of alumina, less than 1% in most cases.

TABLE 15

COMPOSITIONS OF GLASSES INVESTIGATED

Glass no.	Per cent of weight		
	SiO_2	Na_2O	CaO
1	49.7	50.3	...
2	82.6	17.4	...
3	70.0	30.0	...
4	60.0	40.0	...
5	63.0	13.6	23.4
6	60.5	20.0	19.5
7	68.1	21.9	10.0
8	70.0	20.0	10.0
9	54.25	38.0	7.75
10	70.0	10.0	20.0
12	72.25	15.1	12.1
13	73.5	16.5	10.0
14	73.0	12.0	15.0
15	67.5	15.5	17.0
16	64.95	19.3	15.75
17	60.0	30.0	10.0

Results. From the values of log η obtained at definite temps. between 750° and 1500° C, curves were drawn from which the viscosities at round temp. intervals were interpolated.

TABLE 17

VISCOSITIES OF GLASSES INVESTIGATED

Values at round temperature intervals. Interpolated from the log η curves (Fig. 8)

Temp., deg. C	Glass number 1		2		3		4		5	
	log η	$\eta \times 10^{-3}$	log η	$\eta \times 10^{-3}$	log η	$\eta \times 10^{-3}$	log η	$\eta \times 10^{-3}$	log η	$\eta \times 10^{-3}$
1500			2.330	0.21$_4$	1.580	0.038	0.91	0.0081	1.19	0.015$_4$
1475			2.404	0.25$_4$	1.660	0.046	1.000	0.010	1.27	0.018$_8$
1450			2.478	0.30	1.735	0.054$_4$	1.085	0.012	1.35	0.022$_4$
1425			2.560	0.36	1.810	0.064$_8$	1.170	0.015	1.43	0.027
1400			2.638	0.43$_4$	1.887	0.077	1.257	0.018	1.510	0.032$_4$
1375			2.730	0.54	1.960	0.091	1.348	0.022	1.600	0.040
1350			2.835	0.68$_4$	2.037	0.11	1.440	0.027$_8$	1.690	0.049
1325			2.945	0.88	2.117	0.13	1.535	0.034	1.795	0.062$_4$
1300			3.070	1.2	2.205	0.16	1.630	0.043	1.913	0.082
1275			3.209	1.6	2.300	0.20	1.735	0.054	2.055	0.11$_4$
1250			3.355	2.2$_4$	2.403	0.25	1.840	0.069	2.223	0.17
1225			3.515	3.3	2.507	0.32	1.945	0.088	2.415	0.26
1200	0.93	0.0085	3.690	4.9	2.620	0.42	2.050	0.11	2.630	0.43
1175	0.985	0.0097	3.880	7.6	2.735	0.54	2.160	0.14$_4$	2.880	0.76
1150	1.040	0.011	4.085	12	2.860	0.72$_4$	2.270	0.18$_4$	3.150	1.4
1125	1.100	0.012$_4$	4.290	19.5	2.980	0.95$_8$	2.385	0.24	3.450	2.8
1100	1.167	0.015	4.500	31.5	3.104	1.3	2.500	0.31$_4$	3.770	5.9
1075	1.250	0.018			3.235	1.7	2.627	0.42$_4$	4.115	13
1050	1.350	0.022$_4$			3.367	2.3	2.758	0.57	4.450	28
1025	1.477	0.030			3.500	3.1$_8$	2.895	0.78$_4$	4.800	63
1000	1.620	0.042	5.4	250	3.640	4.3$_6$	3.040	1.1	5.165	14$_6$
975	1.780	0.060			3.795	6.2$_4$	3.196	1.6	5.55	
950	1.950	0.089			3.950	8.9	3.350	2.2		
925	2.130	0.13$_4$			4.120	13	3.515	3.3		
900	2.320	0.21			4.300	20	3.683	4.8		
875					4.500	31.$_6$	3.865	7.3		
850					4.700	50	4.055	11		

TABLE NO. 17 (*Continued*)

Temp., deg. C	Glass number 3		4	
	log η	η × 10^{-3}	log η	η × 10^{-3}
825	4.910	81	4.275	19
800	5.140	140	4.515	33
775	5.380	240		
750	5.630	430		

Temp., deg.	Glass number 6		7		8		9		10	
C	log η	η × 10^{-3}	log η	η × 10^{-3}	log η	η × 10^{-3}	log η	η × 10^{-3}	log η	η × 10^{-3}
1500	0.93	0.0085	1.441	0.027_6	1.580	0.038			1.770	0.059
1475	1.030	0.011	1.527	0.034	1.660	0.046			1.865	0.073
1450	1.126	0.013	1.620	0.042	1.753	0.056_6			1.960	0.091
1425	1.224	0.017	1.710	0.051	1.847	0.070			2.007	0.100
1400	1.323	0.021	1.800	0.063	1.940	0.087	0.88	0.0076	2.160	0.14_5
1375	1.427	0.027	1.890	0.077_6	2.035	0.11	0.965	0.0092	2.220	0.16_5
1350	1.515	0.033	1.978	0.095	2.130	0.13_5	1.050	0.011	2.380	0.24
1325	1.612	0.041	2.065	0.11_8	2.230	0.17	1.140	0.014	2.502	0.32
1300	1.708	0.051	2.160	0.14_5	2.330	0.21_4	1.230	0.017	2.640	0.43_6
1275	1.814	0.065	2.258	0.18	2.437	0.27	1.330	0.021_4	2.810	0.64_5
1250	1.905	0.080	2.360	0.23	2.545	0.35	1.430	0.027	3.040	1.1
1225	2.015	0.10	2.470	0.29_5	2.660	0.46	1.540	0.034_6	3.375	2.4
1200	2.143	0.14	2.587	0.38_6	2.777	0.60	1.645	0.044	3.840	6.9
1175	2.315	0.21	2.715	0.52	2.900	0.79_4	1.757	0.057	4.315	21
1150	2.560	0.36	2.860	0.72_5	3.030	1.1	1.870	0.074	4.760	$57._5$
1125	3.000	1.0	3.000	1.0	3.165	1.4_5	1.995	0.099	5.240	174
1100	3.53	3.4	3.140	1.4	3.306	2.0	2.130	0.13_5	5.79	620
1075	3.98	9.5_5	3.290	1.9_5	3.455	2.8_5	2.395	0.25		
1050	4.34	22	3.450	2.8	3.603	4.0	2.700	0.50		
1025	4.65	45	3.603	4.0	3.765	5.8	3.050	1.1		
1000	4.95	89	3.765	5.8	3.930	8.5	3.415	2.6		
975	5.23	170	3.935	8.6	4.103	$12._6$	3.795	6.2_4		
950	5.51	32_4.	4.100	$12._6$	4.284	19	4.200	16		
925			4.270	$18._6$	4.477	30	4.835	$68._4$		
900			4.445	28	4.685	$48._4$	(6.05)	$116_{8.6}$		
875			4.622	42	4.910	81				
850			4.800	63	5.132	13_6.				
825			5.000	100	5.370	23_4.				
800			5.185	150	5.630	430				
775			5.390	24_5.						

Temp., deg.	Glass number 12		13		14		15		16		17	
C	log η	η × 10^{-3}	log η	η × 10^{-3}	log η	η × 10^{-3}	log η	η × 10^{-3}	log η	η × 10^{-3}	log η	η × 10^{-3}
1500	1.627	0.042_4	1.680	0.048	2.43	0.27	1.57	0.037	1.41	0.026	1.08	0.012
1475	1.742	0.055	1.805	0.064	2.52	0.33	1.650	0.044_6	1.49	0.031	1.17	0.015
1450	1.856	0.072	1.930	0.085	2.62	0.42	1.735	0.054	1.57	0.037	1.26	0.018
1425	1.970	0.093	2.060	0.11_5	2.71	0.51	1.823	0.066_5	1.66	0.046	1.35	0.022_4
1400	2.090	0.12	2.180	0.15	2.805	0.64	1.910	0.081	1.750	0.056	1.445	0.028
1375	2.210	0.16	2.310	0.20_4	2.900	0.79_4	2.000	0.10	1.840	0.069	1.535	0.034
1350	2.330	0.21_4	2.440	0.27_5	3.000	1.0	2.098	0.12_5	1.930	0.085	1.625	0.042
1325	2.445	0.28	2.570	0.37	3.09	1.2	2.200	0.16	2.020	0.10_5	1.715	0.052
1300	2.560	0.36	2.700	0.50	3.190	1.5_5	2.320	0.21	2.120	0.13	1.805	0.064
1275	2.680	0.48	2.840	0.69	3.300	2.0	2.450	0.28	2.225	0.17	1.897	0.079
1250	2.794	0.62	2.980	0.95_5	3.420	2.6	2.590	0.39	2.331	0.21_4	1.994	0.098_6
1225	2.910	0.81	3.115	1.3	3.560	3.6	2.735	0.54	2.450	0.28	2.075	0.12
1200	3.030	1.1	3.260	1.8	3.710	5.1	2.890	0.77_6	2.580	0.38	2.180	0.15
1175	3.160	1.4_5	3.405	2.5_6	3.910	8.1	3.047	1.1	2.715	0.52	2.277	0.19
1150	3.293	1.9_5	3.550	3.5_5	4.140	14	3.210	1.6	2.860	0.72_4	2.375	0.24
1125	3.435	2.7	3.700	5.0	4.430	27	3.380	2.4	3.000	1.0	2.477	0.30

Temp., deg. C	Glass number 12		13		14		15		16		17	
	log η	$\eta \times 10^{-3}$	log η	$\eta \times 10^{-3}$	log η	$\eta \times 10^{-3}$	log η	$\eta \times 10^{-3}$	log η	$\eta \times 10^{-3}$	log η	$\eta \times 10^{-3}$
1100	3.590	3.9	3.850	7.1	4.8	63	3.555	3.6	3.150	1.4	2.580	0.38
1075	3.760	5.7_5	4.000	10			3.750	5.6	3.310	2.0_4		
1050	3.942	8.7_5	4.147	14			3.940	8.7	3.480	3.0		
1025	4.145	14	4.250	18			4.145	14	3.670	4.7		
1000	4.365	23	4.460	29			4.370	23.4	3.880	7.6	3.02	1.0_5
975	4.630	42.6	4.615	41			4.605	40	4.105	13		
950	4.900	79	4.770	59			4.875	75	4.360	23		
925	5.180	150	4.927	84.5			5.170	150	4.630	42.6		
900	5.460	290	5.090	120			5.500	31_5	4.920	83	(3.5)	3.1_6
875	5.760	57_5	5.250	180					5.250	180		
850			5.410	260					5.625	420		
825			5.575	37_6								
800			5.73	540								

Graphic representation of results. Isothermal space models were constructed, showing the variations in viscosity with compn. at temps. of 1500°, 1400°, 1300°, 1200°, 1100°, 1000° and 900°C. The contour lines connect the compns. which have the same value of log η at the given temp., as in Fig. 10. The contour lines were then projected on the triaxial compn. field, giving the Figs. 12–18. The term *isokom* is suggested for identical values of η, *i. e.*, for the glasses having different compns. but the same viscosity at the same temp. *Interpolation from the triaxial diagrams.* The viscosities of a glass as P at any given temps. can be obtained by plotting the values of log η against the corresponding values of temp., detd. from the triaxial diagrams. From the curve the value of log η for the temp. in question is read and converted to the antilog, giving the viscosity in poises. *Accuracy and precision of results.* Above 1000 poises the results are probably accurate within 20% and below 1000 poises within 10%. The precision is probably 5% or better. *Influence of dissolved carbon dioxide.* The viscosities of glass No. 9 after being melted in a vacuum furnace until evolution of CO_2 had ceased, were compared with the results obtained on the glass treated in the ordinary manner. The changes in viscosity were within the exptl. error. *Influence of alumina.* 5% of Al_2O_3 was dissolved in glass No. 12, giving it a total content of 6% Al_2O_3. In general the addition of alumina caused an increase in viscosity, the max. increase

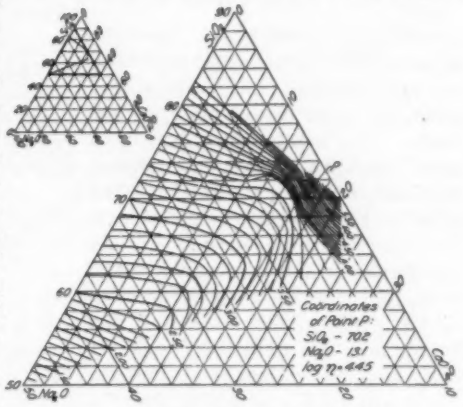


FIG. 14.—Log isokoms at 1100°C.

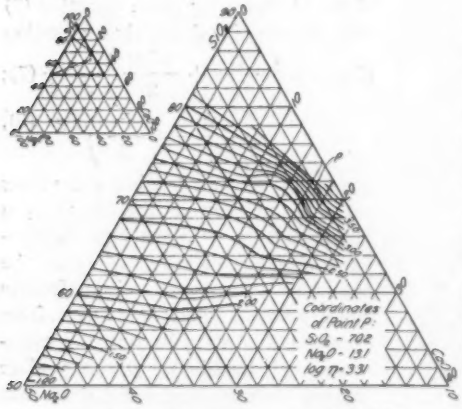


FIG. 15.—Log isokoms at 1200°C.

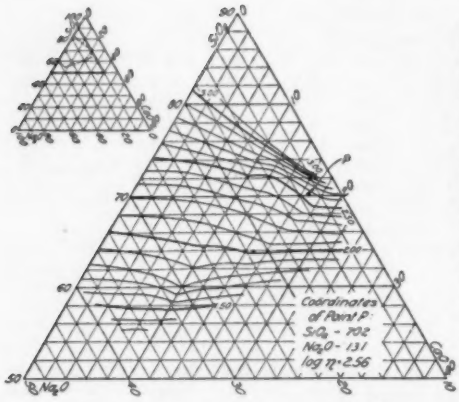


FIG. 16.—Log isokoms at 1300°C.

tained in a platinum wire resistance furnace. The telescope of a cathetometer was focussed on a point at the lower end of the spring and a reading taken. The molten glass was then raised until the surface just touched the lower edge of the cylinder. The cylinder was immediately pulled into the liquid by the capillary forces. At equilibrium another reading was taken. From these readings, the dimensions of the cylinder, the density of the liquid, and the calibration const. of the spring, the surface tension of the liquid was calcd. Assuming that the angle of contact between molten glass and platinum is zero, due to the wetting

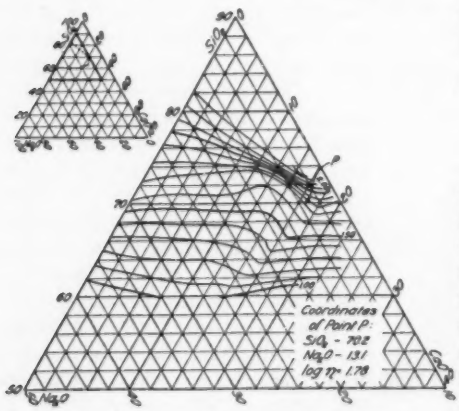


FIG. 18.—Log isokoms at 1500°C.

occurring at 1100°, namely an increase from 4000 poises for the alumina free glass, to 8000 poises for the glass contg. 6%. Towards 1300° and above the increase in viscosity diminishes, and at 960° the viscosity curves cross.

Part II. Surface tensions of glasses at high temperatures. EDWARD W. WASHBURN AND EARL E. LIBMAN. *Ibid.*, pp. 53–71.—*Dipping cylinder method.* Due to the high viscosities of the molten glasses, the only method found to apply was the following modification of Wilhelmy's method. A platinum cylinder suspended on a platinum wire from a Jolly spring was hung above the surface of the molten glass con-

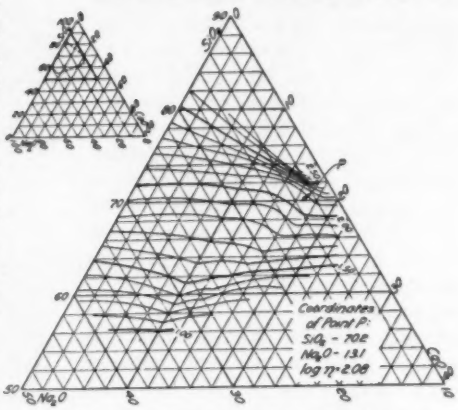


FIG. 17.—Log isokoms at 1400°C.

of the platinum by glass, equation (7) may be simplified to give equation (9): $\gamma = \left(\frac{kgE}{2L} + \frac{hdgw}{2}\right)\frac{1}{\cos\theta}$ (7);

$$\gamma = \left(\frac{k}{2k'L'} + \frac{dw}{2}\right)Eg \quad (9),$$

where γ is surface tension, k the mass necessary to elongate the spring by a unit quantity, $k'L'$ the true circumference of the cylinder, L' being the measured (apparent) circumference and k' a const. for the metal detd. from equation (9) by calibrating the apparatus with liquids of known surface tension—benzene and water, d the density of the glass, w the thickness of the

cylinder, E the elongation of the spring, h the depth of the cylinder in the glass, and g the acceleration due to gravity. In the present method of operating h is equal to E. Due to the expansion of the platinum at the high temps. a coeff. of linear thermal expansion of 0.00001 was allowed. *Density of glasses at high temperatures.* The data detd. by S. H. Li ("Densities of the Soda Lime Glasses at High Temperature," Bachelor's Thesis, Univ. of Ill., 1922) were used. A solid platinum sphere was substituted for the platinum cylinder, and submerged in the molten glass.

Surface tension of soda-lime-silica glasses. The results are given in Table 24, for surface tension measurements (dynes per cm.) made at two temps., 1206° and 1454°C. Solid models were made to correspond to the data, and *isoepitatic* lines (lines of equal surface tension) were drawn on the model. These lines were then projected on the compn. triaxials giving Figs. 24 and 25.

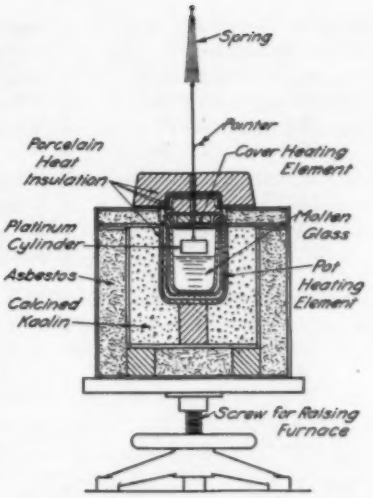


FIG. 22.—Furnace and apparatus for measuring the surface tension of glass at high temperatures.

TABLE 23

DENSITY (IN AIR) OF GLASSES AT 1206°C AND 1454°C

Glass No.	Density, 1206°C	Density, 1454°C
2	2.19	2.15
3	2.42	2.41
4	2.28	2.35
5	2.61	2.59
6	2.46	2.41
7	2.31	2.26
8	2.26	2.20
9	2.26	2.28
10	2.31	2.23
12	2.28	2.23
13	2.31	2.28
15	2.48	2.45
16	2.40	2.43

TABLE 24

SURFACE TENSION READINGS WITH SODA-LIME-SILICA GLASSES

Glass No.	E		Surface tension, dynes per cm.		$-\frac{\Delta\gamma}{\Delta t}$
	1206°C	1454°C	1206°C	1454°C	
2	...	2.438	...	153.7	....
3	2.526	2.296	164.0	148.8	0.061
4	2.442	2.358	156.1	153.6	0.010
5	2.472	2.404	164.1	158.7	0.022
6	2.450	2.422	159.6	128.0	0.013
7	2.339	2.285	150.0	145.9	0.0165
8	2.410	2.212	153.6	140.4	0.054

TABLE 24 (*Continued*)

Glass No.	E		Surface tension, dynes per cm.		$-\frac{\Delta\gamma}{\Delta t}$
	1206°C	1454°C	1206°C	1454°C	
9	2.596	2.411	165.4	153.7	0.047
10	2.516	2.452	164.0	156.4	0.031
12	...	2.384	...	151.6	0.030
13	2.552	2.464	166.9	159.4	0.030
15	2.406	2.246	158.7	145.4	0.0546
16	2.319	2.139	150.1	138.6	0.0465

Application of method when density of liquid is not known. After taking the reading A of the cylinder before immersion, and the reading B_1 on immersion in the glass due to surface tension, another reading B_2 is taken after the furnace has been raised or lowered a known amount. In the modified equation (13),

$$d = \frac{\frac{2\gamma}{g} - \frac{kE}{k'L'(1 + t \times 10^{-5})}}{wh(1 + t \times 10^{-5})},$$

for the reading B_1, $E = h = A - B_1$, for the reading B_2, $E = A - B_2$, and $h = A - B_2 \pm H$ (plus sign if furnace is raised, minus if it is lowered). Substituting these values, and obtaining an equation for each reading B_1 and B_2, and equating them, d is eliminated, giving equation (16): $\gamma =$

$$\frac{\pm k(A - B_1)Hg}{2k'L'(1 + t \times 10^{-5})(B_1 - B_2 \pm H)}.$$

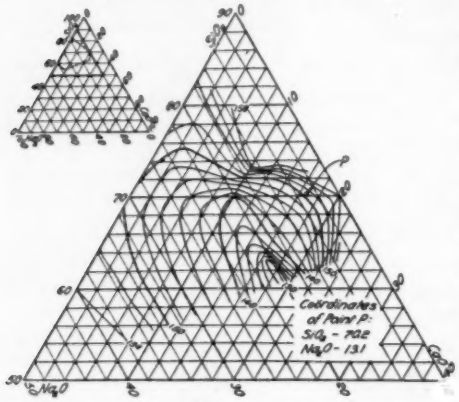


FIG. 24.—Isoepitatic lines at 1454°C.

The results by this method compare favorably with those obtained by the first method. *Temperature coefficient.* The temp. coeffs. are given in the last column of Table 24. They vary between 0.02 and 0.04% per degree C. Surface tension on glass No. 16 was measured at intermediate temps. with the following results: 1454° 137.2, 1397° 140.0, 1356° 143.7, 1314° 146.3, 1289° 148.2, 1248° 149.4, 1206° 150.1. By the use of the temp. coefficients the surface tension of a glass on the triaxial may be approx. computed for any temp. between 1206° and 1454°C.

L. N.

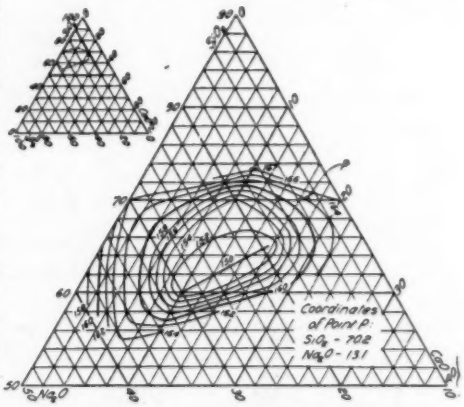


FIG. 25.—Isoepitatic lines at 1206°C.

The use of alumina in glass. R. R. SHIVELY. *The Ceramist*, **4**, 82(1924).—A summary of modern views of the influence of this reagent is given as follows: (1) Reduces the soly. more than lime, (2) Reduces thermal expansion of glass more than lime or magnesia, (3) Alumina aids in preventing devitrification, (4) Reduces

annealing temps., (5) Alumina assists in reducing m. p. in some glasses, (6) Increases luster, (7) Reduces the tendency of soda-lime glasses to scum, (8) Successfully resists failure due to sudden changes in temp. (9) It is reported that it reduces the breaking of ware during finishing. In a number of glasses analyzed it has been found that less than 5% lime combined with 2% alumina, a normal silica content and as much as 20% soda gives a very insol. glass. C. W. P.

The manufacture and uses of fused silica glassware. STAFF ARTICLE. *The Ceramist*, **4**, 41(1924).—A briefly descriptive article of the history of the manuf. of wares of this type and description of the process used. Comparison of the properties of fused silica and hard porcelain is given as follows:

	Fused silica	Hard porcelain
Specific gravity	2.10	2.3–2.5
Tensile strength	Over 700 kg. per sq. cm.	300 kg. per sq. cm.
Resistance to compression	19,800 kg. per sq. cm.	4000 kg. per sq. cm.
Modulus of elasticity	7200 kg. per sq. cm.	8500 kg. per sq. cm.
Average specific heat	.2313 (100°–1600°)	.221 (20°–400°)
Coeff. of expansion	.00000059	.00000380
Heat conductivity	.0026	Over .0025
Melting point	1700°–1800°	About 1670°
Softening point	About 1500°	About 1400°
Elec. resist. at 727°C	400,000 ohms	170,000 ohms
Resist. to penetration	30,000 volts with a thickness of 1.2 mm.	40,000 volts with a thickness of 2.5 mm.
Dielectric constant	3.5–3.6	5.7
Permanency as to weight	High	High
Chem. resist. to H_2SO_4	Absolute	Very high
Chem. resist. against NaOH	Attacked	Attacked slowly
Permeability to ultra violet light	Up to approx. 180 u.u.	....
Hardness	7 according to Mohr	7 according to Mohr

C. W. P.

Quartz glass manufacture. *Nature*, **114**, 516(1924).—(*Physikalische Zeits.*, Aug. 1.) Gives a description of the Herberger method for producing quartz glass for therapeutic and other scien. purposes. This method has been in use for the last 11 years by the firm of Goertz. The finely divided quartz is melted in an elec. fur. in which a vacuum is maintained by continuous pumping until the melting process is complete. The vacuum is then replaced by a gas such as carbonic acid gas under a press. of 8 to 12 atmos., and after a considerable time the fused quartz is allowed to cool. The result is a block of quartz contg. only minute air bubbles in which the air press. is as nearly as possible that of the atmosphere and therefore produces no elastic stresses in the material. According to observations made by G. Joos and described in the same issue, quartz glass made in this way is as transparent in the ultra violet as rock crystal. O. P. R. O.

Equipment for glass pot factory. ANON. *Glass Worker*, **43** [48], 10(1924).—The Ohio Valley Clay Co. of Steubenville, O. installs new equipment. Crusher from the Champion Crusher Co., screens from the Tyler Screen Co., elevators and conveyors from Stephens-Adamson Co., Aurora, Ill. A Dressler tunnel kiln is used for firing and the fired blocks are trued on electrical grinding tables. R. J. M.

Modern methods of glassware decoration. L. KNY. *Glass Worker*, **43** [49], 11 (1924); from Pottery & Glass Trades' Benevolent Institute, England, Mar. 13, 1924.—

Methods of decoration are described including etching, gilding, enameling, glass cameo carving and cased glass. Too much detail to abstract. R. J. M.

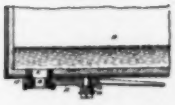
Durability of glass and its importance to the pharmacist. W. E. S. TURNER. *Pharm. J.*, **112**, 264–6(1924).—In a series of 11 samples of soda-lime glass with increasing amts. of CaO, the decrease in soly. upon boiling for 6 hrs. with H_2O, or with 20.24% HCl, or for 3 hrs. with 2 *N* NaOH or 2 *N* Na_2CO_3 is shown in tables and by graph. The usefulness of the *narcotine-HCl reagent* (*C. A.*, **18**, 736; cf. Anneler, *C. A.*, **7**, 2451; **16**, 1294) in detg. the resistance of glass to boiling H_2O is pointed out. S. W. (*C. A.*)

Glass as a raw material in illuminating engineering. ZSCHIMMER. *Glastechn. Ber.*, **1**, 73–6(1923); *Chimie et industrie*, **11**, 930(1924).—An address on the properties and qualities required of glass used for illumination purposes. A. P.-C. (*C. A.*)

PATENTS

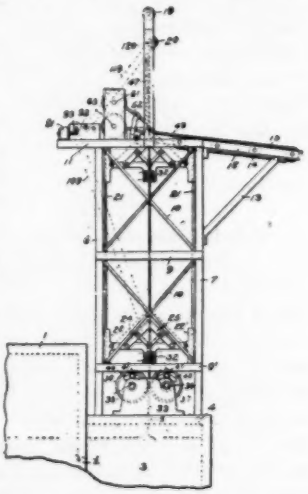
Glass. CHARLES A. KRAUS. U. S. 1,508,455, Sept. 16, 1924. A glass contg. lead oxide and having a coefficient of thermal expansion below about 4.0×10^{-6}.

Glass feeder. CLAUDE W. PLEUKHARP AND HARRY RAYNES. U. S. 1,507,852. Sept. 9, 1924. The combination with a glass feeding vessel having a discharge orifice in its bottom of an arcuate plate having a central handle member and pivotally mounted on the bottom of the vessel and having sliding contact therewith and a series of spigots, each of a different size carried by said plate and adapted to be moved into successive register with the discharge orifice whereby one spigot may be substituted for another, the plate meantime serving to cut off the flow of glass.

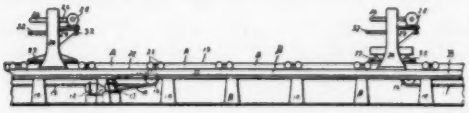


Method of making green scales. WALTER GLAESER. U. S. 1,508,448, Sept. 16, 1924. In a method of producing green scales, the steps which consist in treating calcium citrate with ferric sulphate soln. and then removing the ppt. formed, then adding an ammonium salt removing further ppt., evapg. the filtrate to a strength to produce green scales and brushing the same onto glass.

Apparatus for drawing sheet glass. THOMAS B. CAMPBELL, JR. U. S. 1,508,049, Sept. 9, 1924. A sheet-glass drawing app. comprising a framework, a plurality of vertically reciprocating drawing frames adapted to intermittently grip the sheet being drawn, means for moving the drawing frames upwardly at a uniform and constant speed, means for keeping at least one of said frames reciprocating upwardly at all times, and means for causing said frames to move downwardly at a greater speed than during their upward movement.



Glass-grinding machinery. EDWARD T. BROWN. U. S. 1,508,378, Sept. 9, 1924. In the art of surfacing glass, and wherein the glass sheet is moved in a definite horizontal path beneath a fixedly-positioned instrumentality; a carrier for the glass-sheet and tracks on and between which it moves; a frame supported outside the tracks and extending over the carrier travel path; a surfacing unit mounted in the frame within spaced-apart upper and lower bearings, said unit including a surfacing element operating within the space below the lower bearing, and a shaft for rotating the surfacing element with the shaft mounted in the bearings; means for rotating the



shaft and including a motor supported on the frame and having operating connections with the shaft within the space between said bearings; and unit-supporting and surfacing element positioning means operative to produce controllable gravity-press. of the surfacing element on the sheet, said latter means including a rotatable adjusting element concentric with the shaft and positioned between the motor-operating connections and the lower bearing.

Heavy Clay Products

Mechanical handling equipment in face brick manufacture. G. L. MONTGOMERY. *Chem. Met. Eng.*, **31**, 413–6(1924).—A description of the plant of the Bradford Brick and Tile Co. The shale, shot down with dynamite, is loaded into 5 yd. capacity cars by steam shovels. These cars are hauled to a hopper in the top of the crusher house and automatically dumped. An apron feeder delivers the shale to two single roll crushers in series, from which it is fed onto a belt conveyor, and carried to the top of the grinder house, where it is dumped into bins. From here the crushed mat. is fed by apron feeders to three dry pan grinders, discharged into bucket elevators, which raise the dust to the screening room, and dump it onto "Hummer" screens. The fines pass into a bin while oversize is returned to the grinders. A disk loader beneath the bin delivers the dust to a belt conveyor, which dumps into a bin in the brick making building. Dry press brick, stiff mud brick and flat tile are made, and the machines are fed by belt conveyors. The dry press brick are loaded by hand onto a tunnel kiln car, directly in front of the press. This car is moved by an elec. locomotive to the point where the pusher for the drier takes it. The stiff mud brick are delivered by the cutter to a belt conveyor, from which they are loaded onto tunnel kiln cars by hand. Imperfect brick are left on the belt and dumped onto a return conveyor which returns them to the pug mill. Tile from the tile mach. are piled on Louden overhead carriers. After air drying for 24 hrs., the loaded carriers are moved over above the cars of green stiff mud brick, where a small quantity of tile is loaded on top of each car of brick. The cars are then pushed through the drier and fired in tunnel kilns. The kiln cars are unloaded by hand into carriers on roller conveyors, the carriers are picked up by a monorail crane and unloaded by hand in the store room. M. E. M.

Brick from shale. *Coll. Guardian*, **128**, 768(1924).—The method of mfg. brick from spent shale is first to crush down the shale so that it will all pass, say, a $^1/_4$-in. mesh. The crushed shale is then mixed with about 10% of lime. The 2 are mixed and moistened. They are put under heavy press. in presses designed specif. for this class of brickmaking. The brick, on coming from the press, are strong enough to permit of their being handled and stacked onto wagons. As the wagons are being filled they are placed in long brick tunnels which, when full, are closed up, and steam at atmospheric pressure is turned in. The brick are allowed to remain in the steaming tunnels for about 6 hrs. On withdrawal, they are fit for immediate use. These brick are being largely used in various bldg. schemes and are giving satisfaction. (E. R. Sutcliffe, *Manchester Guardian*.) O. P. R. O.

Makes concrete blocks from brick bats. ANON. *Brick & Clay Rec.*, **65**]5], 313 (1924).—A well-known manufacturer of face and paving brick in the central West found by expt. that concrete blocks made from crushed brick aggregate were economical to manuf. and salable. The bats are crushed in a jaw crusher, and screened, the tailings being returned to a pulverizer. Only 6 or 7% of the resulting aggregate is retained in a $^3/_8$" screen and all passes $^1/_2$". One part cement and 7 parts aggregate are mixed for 5 mins. in a batch mixer on top of an automatic concrete block mach. The blocks are steam cured in tunnels at 100°F for 36 to 48 hrs. They are then sprinkled for 2 or 3 days in the storage yard and in 10 days are ready for the market. P. D. H.

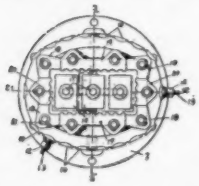
$2700 started this tile producer. ANON. *Brick & Clay Rec.*, **65** [5], 319(1924).—

A novel feature of this plant is a monorail sliding door which has been developed for the fire box openings of the down-draft kilns. The door is composed of a fire-clay slab supported by metal hangers which in turn are attached to rollers that run on a curved rail above the fire boxes. The door is very easily operated and can be kept open any desired distance. P. D. H.

BOOK

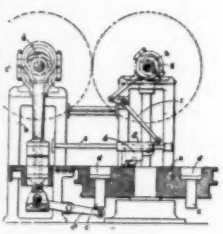
Adaptability of Tile to Hospital Requirements. CARL H. GEISTER (Industrial Fellow, Mellon Institute). Requisite properties of floor tile for hospital use are: resist. to abrasion, to absorption, to staining, to indenture, to heat and to chemicals, as well as a high coeff. of frictional resist. Of special note was the abrasion test. A leather faced wheel revolving against the tile duplicating as near as possible the wear of walking. Other tests were run in the usual manner. Some of the mat. tested were vitreous, semi-vitreous, glazed and rough paving tile, rubbers, linoleums, corks, magnesite compns., asphaltic compns. and marble aggregates. Of these mats., vitreous tile are the only ones not showing some absorption, ranking at the top in the abrasion test, the only group to get an "A" rating in both resistance to chem. and for non-staining qualities; also perfect in ht. resist. Vitreous tile showed no indentation when subjected to press. on a small area, yet show a high frictional resistance against slippage. From all tests conducted, vitreous tile lead in desirable qualities for hospital use. I. A. K.

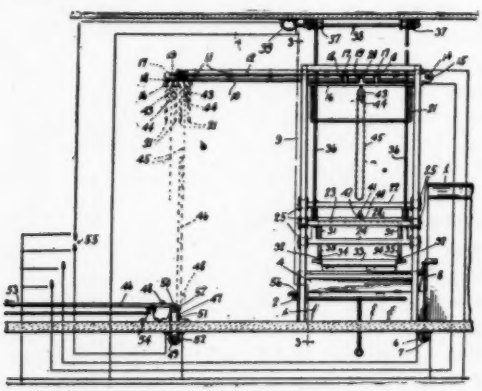
PATENTS



Clay-forming die. DAVIS BROWN. U. S. 1,508,773, Sept. 16, 1924. In a clay forming die, a former, a finisher formed of corner and side sections, and means for adjustably securing the sections relative to the former and to each other.

Brickmaking and like press. THOMAS STANLEY. U. S. 1,510,349, Sept. 30, 1924. In a brickmaking press having a rotary mold table, a pusher horizontally reciprocated above the said table for transferring the blocks of molded material from the said table, said pusher comprising an oil receptacle, a plurality of openings through the bottom of the said receptacle, wicks inserted into said openings and means for supporting the pusher above the table so that the wicks are maintained in contact therewith.

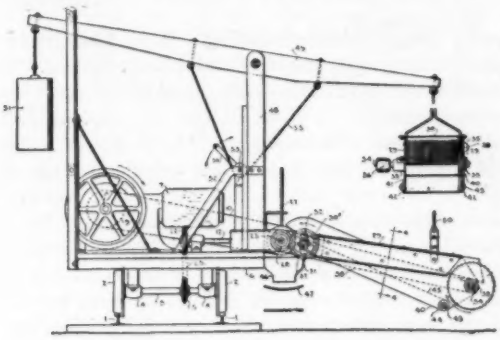




Glass-drawing apparatus. DAVID L. SWINDELL. U. S. 1,509,183, Sept. 23, 1924. An app. of the class described comprising a straight bait bar, a vertically movable carriage, a supporting frame for the bait bar removably supported in the carriage a horizontally movable carriage, means thereon for automatically engaging the supporting frame when the vertically movable carriage brings said frame adjacent the horizontally movable carriage and means for moving said carriages.

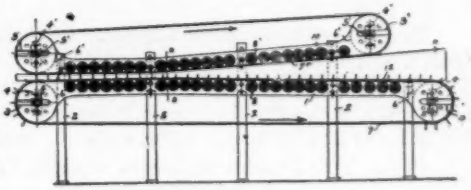
Process for the manufacture of hollow brick closed on all sides. HANS TREITEL. U. S. 1,507,219, Sept. 2, 1924. A process for the manuf. of hollow brick closed on all sides consisting in a hollow brick being first pressed with an open end

and burrs of suitable thickness on two opposite walls and then pressing the burrs toward one another thereby forming a closed end having the desired cross-sectional dimensions. A device for the manuf. of hollow brick closed on all sides consisting in combination of a mold, lateral spaces thereon, said mold and spaces being adapted to be filled with plastic mat., a press ram or plunger adapted to press the hollow brick within said mold and spaces with an open end and thickened walls and press-members adapted to press the projecting thickened parts of the walls toward one another after the plunger is withdrawn, for the purpose of closing the open end of the brick.



Clay-digging machine. JAMES T. POKORNY. U. S. 1,509,173, Sept. 23, 1924. A device of the character described including a framework, a boom pivoted thereto at one end, a gang of pulverizing saws rotatably mounted at the free end of said boom, a digging saw spaced from said pulverizing saws, an operative mechanism carried by the framework through which said saws may be driven, means for elevating and lowering the same, depending side plates carried by the boom, an endless bel moving between the side plates, said belt and plates forming a conveyor disposed to receive from said saws.

Brick-molding machine. JAMES T. POKORNY. U. S. 1,509,174, Sept. 23, 1924. In a molding mach., an endless belt, rollers over which the same operates, a series of molds carried by said belt, said rollers having peripheral ribs and grooves, the ribs of each roller fitting into the grooves of adjacent rollers. In a molding mach., an endless belt, rollers over which the same operates and a series of molds carried by said belt and formed of slightly flexible mat.



Refractories

Novel experiments in casting huge glass pots prove successful. ANON. *Ceram. Indus.*, **3** [3], 186(1924).—The U. S. Bur. of Stand. recently completed the drying of three exptl. pots having outside dimensions of 3 ft. 6 in. in height, 4 ft. 9 in. in diam. and a max. wall thickness of 5 in. 10 T. of plaster were used in making the mold. The equipment available necessitated mixing and pouring 8 batches of 300 lbs. of plaster each in the casting of a single section of the mold. Since the various sections had to be turned to the proper shape it was necessary for the set of the batches of plaster slip to be retarded progressively by the addn. of decreasing amts. of an organic retarder. The mold was cast and turned to shape on a surfacing wheel which functioned as a turning wheel. $1^1/_2$ T. of slip were required to cast one pot and no particular difficulty was experienced in this phase of the work. A satisfactory body compn. is as follows:

Body	%	Grog	%
Feldspar	4.0	Tenn. ball	50
Tenn. ball 5	16 0	Calcined to cone 10.	
Ky. ball 4	9.0	N. C. kaolin	50
N. C. kaolin	12.0	Calcined to cone 10.	
Del. kaolin	4.5	Grog Sizing:	
Ga. kaolin	4.5	10–20-mesh	20
Flint	...	20–40-mesh	50
Grog	50.0	Through 40-mesh	30

P. D. H.

Saving the surface of refractories by using a refractory coating. H. M. CHRISTMAN. *The Ceramist*, **4**, 107(1924).—A refrac. coating is not identical with refrac. cement. It is proposed to apply a superficial coating which will reduce the erosion and corrosion of refrac. Neither compn. nor data are given. C. W. P.

Some aspects of the industrial application of refractories. M. C. BOOZE. *The Ceramist*, 243(1923–4).—A résumé of the charac. and uses of the principal types of refrac. C. W. P.

The true specific gravity and after-expansion of lime-bonded silica brick. W. J. REES. *Jour. Soc. Chem. Ind.*, **43**, 986(1924).—(Meeting of English Ceramic Society, Sept. 18 and 19.) Data are given in a graph and table for 40 brick from Great Britain and France. There is a close relation for brick contg. 1–3% lime, between powder density and the extent of quartz conversion. There is a close reln. for brick of fine and medium texture, but not for brick contg. fragments of $^1/_4$ in. or more in diam. between powder density and after-expansion as detd. by the standard after-expansion test. The powder density may, therefore, be used as an indication of the permanent vol. change which is likely to occur during use. The grading of raw mat. has greater influence on the rate of quartz conversion than variation in the source or type of the raw mat. itself. H. H. S.

The storage of silica refractories. W. J. REES. *Jour. Soc. Chem. Ind.*, **43**, 986 (1924).—(Meeting of English Ceramic Society, Sept. 18 and 19.) Silica brick which had been kept in the open for 6 mos. spalled badly in use, while new brick of the same make, texture, and sp. gr. were satisfactory. The good brick had a cold crushing strength of 3000 lb. per sq. in. while the stored brick had a strength of only 2200 lb. per sq. in. It is found that loss in strength by exposure is in part due to a slight loosening of the bond by hydration and soln. in water, as well as to the phys. effect of frequent wetting and drying. These tests showed little or no distinction between coarse and fine textured brick, but in both cases the brick fired at higher temps. were more resist. to action by water. H. H. S.

The influence of exposure on the chemical and physical properties of certain fire clays. W. HUGILL AND W. J. REES. *Jour. Soc. Chem. Ind.*, **43**, 985(1924).—(Meeting of English Ceramic Society, Sept. 18 and 19.) Samples of 3 clays, 2 of them sandy and micaceous, the other fine-grained and more aluminous, were spread evenly over the bottoms of wooden boxes and exposed to the weather for 12 mos. Small brick were made from the exposed and unexposed samples. Exposure improved the working properties of the siliceous clays, but not materially the aluminous clay, though some impurities were removed. Bacteria seem to promote the decompn. of sulphides in clays, and possibly such decompn. may be accelerated by inoculations. H. H. S.

Some properties of clay-sillimanite mixtures. H. S. HOULDSWORTH. *Jour. Soc. Chem. Ind.*, **43**, 985(1924).—(Meeting of English Ceramic Society, Sept. 18 and 19.) The commercial sillimanite used contd. 32.9% silica, 64% Al_2O_3, with Fe_2O_3 and TiO_2. The grading ranged from 11.8% of mat. between 5-mesh and 10-mesh through inter-

mediate grades to 18% of mat. through 200-mesh sieve. Results are summarized thus: Addition of sillimanite to clay decreases drying and burning shrinkages, increases porosity, and when 50% or more is present, increases refractoriness appreciably. A mixt. of 95% sillimanite with 5% ball clay has a regular coeff. expansion from 15° to 1000°. The rapid expansions of fire clays between 100 and 200°C, and 500 and 600°C, are reduced by the addn. of sillimanite. Chemical attack by soda-lime glasses and basic slag is less on mixt. contg. more than 50% sillimanite than on fire clay or mixt. with less sillimanite than 50%. Sillimanite bonded with 10 g. ball clay is markedly resistant to chem. attack. H. H. S.

Whitewares

The effect of the fineness of grain of flint and feldspar. G. H. BROWN. *The Ceramist*, **4**, 29(1924).—Investigation was made on the influence of fine grinding of flint and feldspar upon a body of the following compn.: Fla. kaolin, 35%; feldspar, 35%; flint, 30%. The bodies were fired to cone 10 and porosity detd. Also the comparative effects of ball-mill grinding versus blunging bodies of the same compn. which were subsequently fired at cone 10. Results obtained were as follows: The body ground in a ball mill had a porosity of 4.96%, while the same body blunged for a similar period of time had a porosity of 9%. Results are summarized as follows: (1) The fineness of grain of commercial flints, prepd. under the same condition, is dependent somewhat upon the nature of the raw mat. from which they are produced. (2) Increased vitrification of a vitreous body may be secured by the use of more finely ground flint. (3) Increased vitrification of a vitreous body may be secured by the use of more finely ground feldspar. (4) The use of finely ground flint and feldspar in a body is conducive to some of the increase in vitrification secured by wet-grinding the flint and feldspar content of bodies in ball mills. (5) The substitution of a finely ground flint for a coarser product permits the use of a higher total flint content in a body. (6) Difficulties from cracking or "dunting" of vitreous bodies may be lessened by the use of a more finely ground flint or of a small propn. of extremely finely ground flint.

C. W. P.

The china ware and porcelain industries in Germany. F. J. M. KOENIG. *The Ceramist*, 269(1923–4).—Historical and statistical, with brief reference to typical compn. of hard and soft porcelain. The compn. of the so-called "light ware" which is still in use is approx. as follows: Refractory clay 25%, kaolin of Halle 30%, quartz or flint 35%, calcium carbonate 10%. The bisque is fired to about cone 3, and a glaze of the character as noted below is used, this melting occurring at cone 07:

$$\left.\begin{matrix} 0.10\ K_2O \\ 0.20\ Na_2O \\ 0.38\ CaO \\ 0.32\ PbO \end{matrix}\right\} 0.28\ Al_2O_3 \left\{\begin{matrix} 2.5\ SiO_2 \\ 0.4\ B_2O_3 \end{matrix}\right.$$

Mfg. of semi-vitreous, table, toilet and sanitary ware is growing extensively. This being produced with a hard (?) glaze, fired from cone 04 to cone 2. The indus. is centered on the Rhine River. Its importance is small as compared with the porcelain indus. Continuous decorating kilns are used in about 50% of the potteries.

C. W. P.

BOOK

Lenox China. The Story of Walter Scott Lenox. GEORGE SANFORD HOLMES. This booklet gives in an interesting manner the life story of Walter Scott Lenox, and the history and development of the Lenox Pottery. Their process of making china is described in a non-technical manner. The booklet is well illustrated. H. G. F.

Chemical stoneware. F. A. WHITAKER. *The Ceramist*, **4**, 70(1924).—The body is a selected blend of plastic close firing stoneware clay to which a small amt. of feldspar and grit are added. The clays are previously washed, blunged and filter-pressed at a pressure of 250 lbs. per sq. in. Non-plastic mats. are added and the mixt. is passed through horizontal pug mill. The prepd. clay is aged in cellars. Circular pieces up to 7 ft. in diam. are jiggered in plaster molds. Piping is manufd. by extruding plastic clay through bronze die. The assembling of parts for complicated pieces requires a remarkable nicety of judgment in order to insure the avoidance of strains in drying and firing. The drying of simple pieces is done over steam coils or in chambers heated with waste heat from kilns. Larger and more complicated pieces are put through special drying chambers where heat and humidity are carefully controlled. Ware is fired in a rectangular down-draft open-fire kiln of special design. These measure 45 x 14 ft. inside and are furnished with 6 horizontal grate furnaces on each side. Gas coal is used as fuel. Time of burn av. about 86 hours. Pieces of all sizes and thickness from $^1/_8$″ to 6″ are fired together in the same kiln. The ware is salted to develop a glaze. Interior surface may be coated with slip or loam glaze. The fitting and assembling of complicated pieces such as exhaust fans, centrifugal pumps, etc., necessitates accurate machining of the individual units after firing. This is done by special designed grinding tools. The total shrinkage of the ware during the process of manuf. is in some cases as high as 2″ to the ft. All finished ware is subjected to finer inspection and test. C. W. P.

Conditions in Saxon porcelain industry. A report of the Vice-Consul, C. T. STEGER, furnished by the Bureau of Foreign and Domestic Commerce. *The Ceramist*, 275 (1923–4).—General unfavorable situation in Saxony due to the decline of the value of the mark. The domestic demand is only for cheaper grades. Coarser products are increasing rapidly. C. W. P.

Equipment and Apparatus

The use of auxiliary or portable fans for watersmoking. ANON. *Brick & Clay Rec.*, **65** [5], 327(1924).—Portable fans are being used to great advantage to hasten watersmoking and cooling of kilns. An illustration shows a fan being used in a slightly different manner, in that it is connected to a kiln stack by a sewer pipe connection set in the stack wall at an angle of about 45°. The firing time has been reduced from $8^1/_2$ to 5 days. P. D. H.

Facts on the problem of electrification. JAMES R. DOWNS. *Brick & Clay Rec.*, **65** [5], 323(1924).—The greatest hindrance to a rapid change from present methods to elec. drive is apparently the lack of accurate information on the power requirements of the different machines. A 10 ft. dry pan in a given plant requires 32 h. p. whereas the same sized pan in another plant grinding the same class of mat. requires from 75 to 100 h. p. depending upon the variation in the amt. and condition of the mat. in the pans; d. c. motors should not be installed in clay plants. While the a. c. motor is the more desirable, the standard general purpose squirrel-cage type is not as satisfactory as that known as the high torque motor. Bearings should be made dust-proof and motor driving pans, pug mills and brick machines should be of the three bearing type, that is, with outboard bearing and sub-base, to provide for heavy overloads. Individual motor drive is more satisfactory than group motor drive, as friction losses in the latter average about 35% and the former greatly facilitates repairs. Speed regulation is very important to secure uniform production. The cost of power varies from $1.50 per M brick in the ganister district to $.94 per M on a plant using hard shale making face brick in the Pittsburgh district. A list of the equipment used in this plant is

given including the various sized motors. A table also gives a complete chart of production, power consumption and costs over a 12-mo. period. P. D. H.

Removing ashes from radiated heat drier. HAROLD COPPING. *Brick & Clay Rec.*, **65** [1], 42(1924).—The device described is C.'s own idea. A very complete sketch accompanies the article. The equipment consists of a light overhead track rail extending the full length of the fireman's pit and suspended from the timbers or I-beams spanning the pit and upon which the drier tracks rest, a trolley and a specially constructed bottom dumping bucket. Above the pit and over the "cooling tracks" is a short length of track (about 20 ft.) hung at right angles to the pit and upon which a "hay carrier" operates. A small hand windlass attached to a post against the wall in the pit completes the outfit. The ash bucket has a capacity of about 20 cu. ft. and the bail is of such length as to place the bucket at a convenient shovelling height thus eliminating the necessity for a chain hoist. The bucket upon being filled is moved along the trolley to the point beneath the "hay carrier" track, where the cable is hooked onto the bail and by means of the windlass, the bucket is elevated and run out over a wagon, thus disposing of the ashes with one shovelling. P. D. H.

A few hints on clay plant hauling equipment. B. F. TOWNSLEY. *Brick & Clay Rec.*, **65** [1], 30(1924).—The particular type of mechanical haulage for a given plant depends on local conditions. Rope haulage should be employed in plants where the pit is located near by and the grade is above $2^1/_2\%$. If less than $2^1/_2\%$ other methods may be resorted to with a possible saving. A 1% grade takes almost double the energy that is necessary to move a load on a level track. In general practice, the haulage capacity of a locomotive is 13 T. per ton of locomotive weight, on the level, while with a 1% grade this is reduced to 8 T. and with a 5% grade to 3 T. The gasoline or elec. type of locomotive is generally preferred to steam. The advantages of the former are its low first cost, which is about $750 per T., its simplicity of opern. and normal fuel consumption cost of about $1.00 per T. weight per day. This type would accordingly be desirable in plants where requirements are for a less-than-three-ton locomotive. Elec. locomotives propelled by storage batteries offer a reliable, flexible and economical source of power. The first cost per T. wt. is about $1400 and the cost to operate is about 10c per T. per day, and often less as the batteries are charged at night during the off-peak load of the plant. The proper size and type of car is another important factor. Standard practice dictates the use of the V-bottom, steel, side dump cars, where, in many instances, more efficient types could be used. Storage battery trucks are now being used for coal distribution, ash removal and green and fired ware transportation. Portable platforms facilitate the movement of ware. A truck of this type with one man can equal the capacity of from 5 to 10 men with wheelbarrows. P. D. H.

Development in dry pan construction. P. B. REED. *Brick & Clay Rec.*, **65** [5], 322(1924).—The rate of output of a dry pan depends much more upon the design and location of the mullers than upon the screen plate area. An older type of 9 ft. pan had 12 in. by 54 in. mullers, each having a wt. of 7429 lbs. The width of the screen plates was 18 in. and the grinding area in one revolution was 3419 sq. in. The diameter of the newer type of pan was reduced from 9 ft. to 8 ft. 6 in. by taking 3 in. off of the outside of the screen plates. The mullers were moved out 3 in. thus taking 2 in. off the inside of the screen plates. The dimensions of the mullers were $14^1/_2$ in. by 55 in. each having a wt. of 9301 lbs. The width of the screen plates was 12 in. and the grinding area in one revolution was 5938 sq. in. It was also found that wider slots in the screen plates produced more fines. The $^1/_{16}$ in. perforations were replaced with openings from $^1/_4$ in. to $^1/_2$ in. and even larger, the limit being when too great a load is placed on the elevator and screen due to too large a percentage of tailings being returned to the

pan. By selecting the correct screen openings the new 8 ft. 6 in. pan will grind from 40 to 50 T. of 12- to 14-mesh hard fire clay dust per hr. P. D. H.

Things to remember when you buy belts. E. H. COLE. *Brick & Clay Rec.*, **65** [5], 326(1924).—Care should be taken in choosing the proper type of belt for the purpose intended. The size is also very important. When changing pulleys, the width should always be increased where possible, as this increases the area of belt contact with the pulley without increased thickness of belt. The pulleys should be kept as large in diameter as possible as it is most destructive to a belt to run over small pulleys. A new belt should be run slowly until it has adjusted itself to the stresses. Belts should be kept pliable by the use of a good belt dressing. Rosin is very undesirable. In joining a belt, laboratory tests have shown that a fastener which is designed to secure a firm hold on the threads of the belt is more satisfactory than rawhide lacing.

P. D. H.

The formation of kaolin at moderate depths. A. L. PARSONS. *Am. Mineral.*, **8**, 157–62(1923).—The feldspars and feldspathoids are the principal minerals from which kaolin may be formed. Carbonic acid is regarded responsible for most of the kaolinization of surface deposits. In a kaolinized dike at the Helen Fe mine (Ont.) CO_2 was liberated by the oxidation of a large body of siderite, the Fe forming goethite. The source of CO_2 in the kaolin deposits at Huberdeau, Que., was probably a cryst. limestone sepd. from the kaolinized granite and gneiss by a shattered quartzite.

E. F. H. (*C. A.*)

Drying. Industrial drying. The apparatus and how it works. LUCIEN BUCK. *Chem. Met. Eng.*, **29**, 626–31(1923).—The general principles of drying with air are set forth. There is a limit to the speed at which any material can be dried. If this limiting speed is exceeded, injury such as checking, warping, cracking, etc., usually results. Suggestions are made to designers of driers. Heat insulation is discussed. Driers are classified and as an example data are given and calcns. made for a drier for coco fiber mats. E. R. G. A. (*C. A.*)

Self-cleaning continuous filter. ANON. *Chem. Met. Eng.*, **29**, 1193–4(1923).—1 illus. The ideal condition for filtration would be: (1) filtering performed by the solid matter in the liquid filtered; (2) the layer of this solid matter must be constantly removed without exposing the bare surface of the screen or filtering device; (3) the solid material should leave the filter with but a small % of moisture—dry if possible. The upper part of the filter consists of a cylinder ending in a short cone resting on bars placed radially inside of a shell, which rests on a saddle, permitting the escape of the filtrate into a surrounding basin. The saddle supports the bars and its central hole corresponds with a hole in the center of the basin, and is closed by a conical plug operated by hydraulic pressure. The displacement center is continued upward into the mixer in which a reciprocating plunger passes up and down into the upper cylinder to the beginning of the short cone. The functioning is explained. The design allows employment of any pressure that the shell will stand, the bars cannot become distorted, and there is complete absence of screens, cloth, and moving parts. W. H. B. (*C. A.*)

Fine screening equipment—its selection and operation. F. S. CURTIS. *Chem. Met. Eng.*, **29**, 759(1923).—Screening equipment must be adjustable. Specifications stated in fractions of an inch instead of in "mesh" become more definite and dependable. The use of a screen in closed circuit with grinding equipment increases the output without increasing the power requirement. W. H. B. (*C. A.*)

Equipment for difficult screening. L. H. STURTEVENT. *Chem. Met. Eng.*, **29**, 1063(1923).—A description of the vibrating screen is given, pointing out its applications and advantages. L. A. P. (*C. A.*)

Fuel oil viscometers. W. H. HERSCHEL. *Chem. Met. Eng.*, **26**, 1175(1922).—

After making the Couette correction (0.311 × diam.) and the kinetic energy correction coeff. (1.128) the equation for the normal Saybolt Furol viscometer is *kinematic viscosity* = $0.0220t-(2.03/t)$. The corresponding equation for the Redwood Admiralty viscometer is *kinematic viscosity* = $0.0239t-(0.403/t)$. By using the equation for the Saybolt Universal viscometer, *kinematic viscosity* = $0.00220t-(1.80/t)$. With the above, H. calcs. tables for conversion of time Saybolt Furol to Universal and Redwood Admiralty. E. C. B. (*C. A.*)

A simple thermoregulator for use with gas burners. Fr. Viktorin. *Mikrokosmos*, **17**, 138–9(1924).—A simple and inexpensive thermoregulator for the control of thermostat or incubator temps. is made in a test-tube. A cork contg. a 3 mm. internal diam. glass tube extending 4 cm. upward from the cork is fastened inside the test-tube about 5 cm. from the bottom. Hg fills the bottom of the test-tube and rises to the middle of the 3 mm. glass tube. The inlet tube leading from the illuminating gas supply passes through a cork in the top of the test-tube. The inner end is drawn to a long capillary and is cut off at an acute angle. The opening thus formed is adjusted at the proper height inside the 3 mm. tube so that expansion or contraction of the Hg automatically acts to diminish or increase the size of the opening. The illuminating gas is conducted from the thermoregulator to the burner by means of an exit tube through the upper cork. The test-tube regulator is installed in the thermostat or incubator. Minute details of construction are given. R. L. D. (*C. A.*)

Kilns, Furnaces, Fuels and Combustion

Rectangular kiln bracing. Wm. Burgess. *The Clay Worker*, **81** [7], 669(1924).—One foot rise to each four ft. of width gives the longest life to kiln crowns. The crown should be built in sections to facilitate repairs. Kiln crowns have lasted 12 to 14 yrs. without renewing any part. One section 35 ft. in length lasted 16 yrs. without repairs. There should be as few flues as possible in the main walls. Half circle arches on rectangular kilns are not satisfactory as they are sure to bulge on the quarters or one side will rise and let the other side flatten. The best crown is made of wedge brick to properly fit the circle. As this would require special brick, wedge brick alternating with standards are satisfactory. Crowns should not be built with all standard brick with heavy mortar to keep the bed joint radial. A single 10-in. I-beam has been found stronger and cheaper than the old type of rod-braced double rail brick stay. The tie rods should be secured with forged loops over the I-beams. Each tie rod across the kiln should be provided with a turnbuckle and 2 or more should be used in the rods running lengthwise. Two runs of 60-lb. railroad iron should be placed around each kiln, one a little above the fur. arch and the other directly behind the skewback on the sides of the kiln. They should be fishplated together and placed close to the buck stay, on the ends of the kiln on the same level as the sides, one coming about half way down on each side of the wicket opening and the other one just over the top of the wicket arch. Expansion joints should be provided between the floor brick and the kiln wall. The lining should be thoroughly bonded to the main wall. The backing-up brick should not be loosely laid. Brick chips when used to loosely fill the voids will wedge down into the crevices and cause "crowding" as the wall contracts and expands. P. D. H.

A comparison of gas- and coke-fired drying stoves. T. W. Barley. *Jour. Soc. Chem. Ind.*, **43**, 985(1924).—(Meeting of English Ceramic Society, Sept. 18 and 19.) City gas was used for drying large molds in steel works until post-war conditions made it too expensive. It was substituted by the Hüttenes coke-fired, air-blown fur., which with minor modifications has been found very satisfactory. The hot gases are met by a pre-htd. jet of compressed air at 80 lb. per sq. in. press. the products of combustion

being thus projected into the drying chamber at a high velocity. All molds are thoroughly dried at the end of 15 hrs. no mold being found burned or imperfectly dried. The av. working temp. for mold drying is 225°C, for large cores 200°C, and for small cores 180°C. H. H. S.

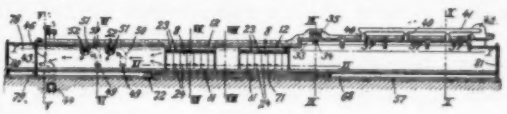
American furnaces for the treatment of iron and steel. BRUNO SCHAPIRA. *Feuerungstechnik*, **12** [21, 22, 23], 174, 184, 189(1924).—Describes in detail the function and different types of such furnaces and discusses the importance of the correct selection of refrac. for lining same. For the crown of the Martin fur. acid (silica) brick are used and for the hearth either an acid or a basic (magnesite) brick depending upon the conditions. The author refers to the research work being undertaken at this time by the Refractory Mfrs.' Assoc., etc., to bring about the following improvement in their product. (1) The manuf. of a more even product by keeping close check on raw mat., substituting dry grinding and screening for wet, close control of water content, (2) raising m. p. by adding new mat. with a m. p. 100° to 160°C higher than the best refrac. used to date, (3) increased resist. to temp. variations through larger use of calcined clays, control of grinding, improved methods of molding and use of better quality clays, (4) min. change in volume through use of brick fired at high temp. in elec. fur. and by using special raw mat., (5) resistance to action of slags. Several newer raw mat. of high refractoriness are mentioned, (*a*) Missouri diaspore which melts at cone 40 and is dense and slag resisting, (*b*) Calif. periclase, a cryst. oxide of magnesium, (*c*) spinel, (*d*) sillimanite, (*e*) fused silica. F. A. W.

Operation of the Shaw gas kiln. LEROY H. MINTON. *The Ceramist*, **4**, 15(1924).—A compartment kiln for finer grades of ware. Twenty-five are operg. and being built in England, 2 or 3 in France, and 2 are in use and 1 being built in the U. S. The kiln is used for all types of ware, excepting those requiring salt glazing. The kiln normally consists of 16 chambers, usually placed in 2 rows of 8 each with passageways between, the whole occupying an area of 100 ft. x 61 ft. The compartments have a setting space of 7 ft. x 23 ft. x 8 ft. The kiln is fired from gas produced from coal. A saving of 50–80% fuel over that required in periodic kilns is claimed. Fuel consumption of kilns now fired in England is given as follows: fire brick to cone 10 = 350 lbs. of coal per 1000 brick; glazed brick to cone 10 = 675 lbs. of coal per 1000 brick; architectural terra cotta to cone 6–7 = 19 tons of coal for 17 tons terra cotta per week. Comparison of fuel consumption of the Shaw kiln with periodical muffle kilns: for the muffle kilns the av. coal per kiln fired was 23.26 T. For the gas kiln the av. was 3.36 T. This is equiv. to 6.72 T. for a muffle kiln on the basis of output. On a direct comparison this shows the saving to be 72% of the coal required for periodic kilns. It is possible to fire different kinds of ware maturing at different temps. in different chambers. It is also possible to regulate the atmos. of the firing chamber so as to fire glazed ware without the use of muffle or saggers. The following results have been attained in this country: Vitreous sanitary ware, glost firing, 2.6 T. per coal per chamber containing 240 closet bowls or 300 tanks. Fire clay sanitary ware required 3.36 T. of coal per chamber containing 10 T. of ware and $7\frac{1}{2}$ T. of fixtures fired to temp. of cone 9 down. Advantages claimed for the kiln are: (1) Saving of 50–80% fuel over periodic kiln. (2) Lower operg. cost. No coal or ashes to be carted in and out, or to block the kiln room. (3) Ease of operation. Perfect control at all times. One man can handle gas producer and kiln. (4) Lower labor costs. A kiln occupying 100 ft. x 61 ft. has a capacity equal to periodical kilns occupying 350 ft. x 40 ft. All labor of conveying ware is greatly reduced. No night loading is required as for tunnel kilns. (5) Compactness. Comparison with the Shaw kiln 100 ft. x 61 ft. with a tunnel kiln 350 ft. to 450 ft. long makes it evident to any engineer which is better adapted to fit in with modern factory design. This is a very important point for plants already built. (6)

Greater flexibility. Chambers may be set with wares requiring different maturing temp. This is impossible in any tunnel kiln. (7) Ease of repairing. Kiln does not require stopping operations for any except major repairs. (8) Quality and cost. Produces highest percentage of quality ware at the least cost per unit. This is a final argument for any comparison. C. W. P.

PATENT

Tunnel kiln. CONRAD DRESSLER. U. S. 1,509,195, Sept. 23, 1924. A tunnel kiln comprising a main chamber through which the goods to be treated are moved, means situated approx. at the center of said chamber for developing a high temp. therein, and gas propelling mechanism located within the kiln and associated with the forward heating zone of said main chamber and adapted by its propulsion to equalize the ht. distribution in said zone.



Geology

New uses of non-metallic minerals. W. M. MYERS. *The Ceramist*, **4**, 99(1924).—The compn., occurrence, properties and uses of the following minerals are described: The andalusite group, beryl, spinel, and bentonite. (1) *Andalusite* occurs in a deposit of commercial importance in Mono County, Calif. It is so pure that no other treatment than crushing is necessary. The ore is transported by mule trains and wagon to the railroad and shipped to Detroit. Production at present amts. to 70 T. a week. At the pottery it is crushed in Blake jaw crusher, then milled in a Hardinge ball mill, passed over a Dings magnetic separator to remove the abraded iron and finally ground in a Hardinge pebble mill lined with special sillimanite porcelain and using balls of the same material to avoid contamination. The finely ground andalusite is mixed with other porcelain making mat. and ground wet to pass 300-mesh screen. The resulting batch is molded and fired at such a temp. that the andalusite inverts to sillimanite. (2) *Cyanite* occurs in deposits of commercial importance in Wyo. and Va. Commercial possibilities are not fully known. It inverts to sillimanite when heated to sufficiently high temps. (3) *Sillimanite*. The only known large deposits occur in India. (4) *Beryl*. The annual production does not exceed 10 T. It is found associated with feldspar and mica. Small amts. are shipped to Germany for use in the manuf. of beryllium salts and metal beryllium which is said to be used in the prepn. of certain alloys. (5) *Spinel* has been found in many scattered localities, but not in sufficient quantity to be of importance. Synthetic spinel is made by combination of magnesium oxide and alumina from the mineral alumite. (6) *Bentonite* and *Montmorillonite*. The two are so similar that it is practically impossible to distinguish between the same. C. W. P.

Bauxite. J. T. FULLER. *Chem. Bull.* (Chicago), **11**, No. 2, 31(Feb., 1924).—General article. J. J. H., JR. (*C. A.*)

Chemistry and Physics

Preparation of alkali silicate from calcined infusorial earth. E. KLEINSCHMIDT AND F. STEINBERG. Ger. 369,062, *Oil & Col. Trade Jour.*, **66**, 1052(1924).—Infusorial earth, calcined out of contact with air, is treated with dissolved alkali, a clear, colorless soln. of alkali silicate being obtained.

Production of alumina. W. BOEHM. Ger. 369,826, *Oil & Color Trade Jour.*, **66**, 1051(1924).—An elec. current is passed through a mixt. of clay with alkali lye, or with such alkali compds. as are capable of decompn. of a silicate.

A rapid method for the determination of true (or powder) specific gravity. W. HUGILL AND W. J. REES. *Jour. Soc. Chem. Ind.*, **43**, 986(1924).—(Meeting of English Ceramic Society, Sept. 18 and 19.) The app. used consists of a conical flask with a long neck, at the lower end of which is a wide bulb. At the bottom of the neck is the 250 cc. mark, and above the bulb the neck is graduated in sp. gr. from 2.00 to 2.70 so that the sp. gr. may be read off directly. Xylene is poured into the flask up to 250 cc. and exactly 100 g. of dry powder is then dropped gradually into the flask. After standing 2 mins. to let air bubbles rise, the sp. gr. is read off. Crushing the dry brick to pass a 30-mesh sieve yields results accurate within 0.01%. H. H. S.

Sedimentation of bentonite. H. F. COWARD. *Jour. Chem. Soc.*, **125**, 1470–4 (1924); *Jour. Soc. Chem. Ind.*, **43B**, 786(1924).—Bentonite readily forms milky suspensions by shaking with water after soaking for a few minutes. The suspensoid is negatively charged, and is reversibly coagulated by suitable addns. of electrolytes. The easy prepn. of these suspensions suggests their possible use as a mat. for colloid investigations. H. H. S.

Emilium. LOISEL. *Jour. Soc. Chem. Ind.*, **43**, 986(1924).—(Meeting of French Academy des Science, Sept. 15.) A new radio-active body to which is given the name emilium yields an emanation in the gas given off by thermal springs at Bagnoles de l'Orne, and in the granite rocks from which issue the springs. H. H. S.

Determination of magnesium in aluminum, zinc and lead alloys. B. FETKENHEUER AND A. KONARSKY. *Wiss. Veröff. Siemens-Konz*, **3**, 19–21(1924); *Jour. Soc. Chem. Ind.*, **43B**, 791(1924).—The non-ammoniacal soln. is poured into KOH. $Mg(OH)_2$ is pptd., filtered, dissolved and after treatment with NH_4Cl, NH_4OH, NH_4HS, pptd. as phosphate. H. H. S.

Thermal conductivity and compressibility of several rocks under high pressure. P. W. BRIDGMAN. *Am. J. Sci.*, **7**, 81–102(1924).—Summary: The thermal condy. of pipestone, talc, Solenhofen limestone, basalt, Pyrex glass and rock salt has been measured up to 12,000 kg./cm.^{2} at 30° and in most cases at 75° also. The condy. increases with rising pressure by an amt. which may vary from 0.1% per 1000 kg. at 30° for Solenhofen limestone to 3.6% for rock salt. Probably for the ordinary rock of the earth's crust the effect is not over 0.5% at ordinary temps. The abs. condy. and its pressure coeff. may either increase or decrease with rising temp. A simple hydrostatic pressure applied to substances of the character of those measured does not in general produce a uniform change of vol., but the effects are complicated. The relation between pressure and deformation may be affected by hysteresis in a direction the reverse of normal. This occurs in pipestone, Solenhofen limestone, and basalt in amts. varying from a few per cent to 18% of the whole deformation. Talc and pipestone show large differences of linear compressibility in different directions; this effect was not investigated for the other materials. Pyrex glass has an abnormal increase of compressibility at high pressures. The geol. consequences of the foregoing results are discussed.
L. W. R. (*C. A.*)

Decomposition of pyrite by heat. MLLE. G. MARCHAL. *Bull. soc. chim.*, **35**, 43–7(1924).—Very pure pyrite, finely ground, was heated both *in vacuo* and in a current of N. *In vacuo* decompn. became evident at 500°. The loss of wt. was 1.22% per hr. at this temp. and increased to 2.03% per hr. at 550°. At 670–80° decompn. into S and FeS was complete in 8 hrs. The S deposits on the tube walls in cryst. form and high purity. The decompn. is rapid at 850°. At 1000° or higher the sulphide product corresponded closely to $FeS_{0.9}$. Heating in a current of N at 850° for 1 hr. gave complete decompn. into FeS and pure cryst. S. A. R. M. (*C. A.*)

Study of clays. V. The action of heat. O. BOUDOUARD AND J. LEFRANC. *Bull. soc. chim.*, **33**, 1627–40(1923); cf. *C. A.*, **17**, 3009.—The ignition loss of 7 clays and 2

halloysites, heated to various temps. from 182° to 1000°, was studied. The hygroscopic H_2O was evolved continuously and slowly up to 450°. The liberation of combined H_2O started at 450° and was complete at 500°. Some anomalies were noted. The halloysites showed, at about 800°, a further definite loss of H_2O. One of the clays in particular showed a similar loss of H_2O at 800°. C. H. K. (*C. A.*)

The estimation of chromium in nickel-chrome alloys. "METT." *Chem. Age* (London), **9**, 364(1923).—Heat 0.2–1 g. of alloy in a Ni crucible with 10 g. Na_2O_2. Ext. the Na_2CrO_4 with water, make acid with HNO_3, neutralize with NH_4OH and then acid with AcOH. Ppt. $PbCrO_4$, filter, dissolve in 2 *N* H_2SO_4 and det. Cr volumetrically with $FeSO_4$ soln. and $KMnO_4$ in the usual way. W. T. H. (*C. A.*)

Behaviour of gases in contact with glass surfaces. D. H. BANGHAM AND F. P. BURT. *Roy. Soc. Proc.*, **105A**, 481–8(1924).—The sorption of carbon dioxide by fine glass wool has been found to be very accurately represented by the equation, $s^m = kt$, where s is the amt. sorbed under a certain press. during the time, t, and the index, m, increases with the pressure. An equation showing desorption has also been deduced. Further, the quantities of sorbed gas in approx. equilibrium with a given pressure, have been found to be expressed by the Freundlich equation, $s^n = k'p$, where n is a constant charac. of the gas, being apparently larger the greater the soly. of the gas in water. M. S. B. (*J. S. C. I.*)

Calcium sulphate solutions. P. JOLIBOIS AND L. CHASSEVENT. *Compt. rend.*, **178**, 1543–6(1924).—The soly. curve of $CaSO_4$, $^1/_2H_2O$ is traced in its metastable region and the rate of crystn. of the dihydrate from supersatd. soln. plotted. Seeding the soln. with the dihydrate starts immediate crystn., but the addn. of anhydrous calcium sulphate (calcined at 200–1000°) has no effect. The explanation of the setting of plaster of Paris, calcined at high temp., must, therefore, not be sought in the starting of crystn. but rather that transformation into the hemihydrate in contact with the soln. is slower the higher the temp. of calcination in consequence of a diminution in the active surface. J. W. B. (*J. S. C. I.*)

PATENTS

Process for producing and utilizing alkalies and alumina. ALFRED H. COWLES. U. S. 1,508,777, Sept. 16, 1924. A process of treating leucite, feldspar and like alkali-alumina-silicates, which consists in subjecting them to a sintering process with such proportions of sodium metal carbonate and an alkali earth metal carbonate as will give a sintered product containing one molecular weight of silica to two molecular weights of alkali earth oxide and less than one and seventy-six hundredths molecular weights of alkali metal oxide to one of alumina, and leaching the sintered product.

Process for the production of alumina and nitrates. HANS JOACHIM FALCK AND THOR MEJDELL. U. S. 1,507,993, Sept. 9, 1924. Process for the production of alumina and nitrates which consists in forming a mixt. of nitrates containing aluminum nitrate, mixing such mixt. of nitrates with an alumina-contg. mat. in such a quantity that the resulting mixt. will not melt during the subsequent htg., htg. said resulting mixt. in the presence of a basic subs. and working the product of the htg. opern. for the recovery of alumina and nitrates.

Process of producing aluminum chloride and sodium silicate. SAMUEL PEACOCK. U. S. 1,507,709, Sept. 9, 1924. The process of producing aluminum chloride, and sodium silicate, from naturally occurring aluminum silicates, which consists in calcining said silicates and mixing the same with sodium chloride; subjecting the mixture thus produced to a reacting temp. to produce the desired aluminum chloride and sodium silicate; passing free nitrogen over the charge to sweep out the volatile aluminum chloride and recovering said sodium silicate from the fur., substantially as described.

Fire-resisting paint. NEVIL MONROE HOPKINS. U. S. 1,507,181, Sept. 2, 1924.

The herein described new paint compn. consisting of a water soln. of sodium silicate in the proportions of $1^1/_2$ pints; sodium fluoride $^1/_2$ pint; 6 oz. finely divided asbestos and 6 oz. asbestine admixed with sufficient kaolin, and zinc oxide to increase the hiding power of the paint and sufficient coloring matter to provide a predetd. color thereto.

General

Pottery Expansion in United States breaks record in 1923. ANON. *The Ceramist,* 278(1923–4).—42 glost and biscuit kilns for general ware, and 6 double decorating kilns were built in the 12 months' period prior to December 4, 1923. This is a greater increase than any single year in the history of the industry. Notes relating to charges and improvements in individual plants. C. W. P.

Safety work in the pottery industry. The New Jersey State Industrial Safety Museum. LEROY W. ALLISON. *The Ceramist,* 249(1923–4).—A description of the purpose and equipment of the N. J. State Industrial Safety Museum with special reference to its exhibits and devices recommended for the ceramic industry. C. W. P.

Mineral industry of the British Empire and foreign countries. *Imp. Min. Resources Bur.*(1924).—Statistical Summary: Production, imports and exports, 1920–22. O. P. R. O.

Swedish testing laboratory. *Indus. Australian and Mining Stand.,* **72,** 249.—The Swedish Testing Laboratory at Stockholm announces that it is open to exporters from other countries desirous of having samples of any mat. tested when in doubt as to whether they comply with Swedish import regulations. The Testing Institute is managed by a board of directors and has skilled experts on its staff. O. P. R. O.

Standardization of scientific glassware. *Nature,* **114,** 485(1924).—Units of volume, the first rept. issued by the Joint Comm. for the Standardization of Sci. Glassware records unanimous recommendation to discard the cc. as the standard unit for scien. glassware and to institute therefor the liter and the milliliter. As some chemists prefer the Mohr unit, the Comm. adds 2 further recommendations, to obviate confusion between the 2 systems, although it hopes that in time the liter and the milliliter will be adopted exclusively. It recommends that vessels graduated on the Mohr system should be marked "g. w. a." (grams of water in air) and the numerical relation between the units shall be 1000 g. w. a. = 1002 ml. Whereas the vol. of a body of simple geometrical form is readily calcd. from its linear dimensions, the vol. of a hollow vessel designed to hold a fluid is detd. more easily and more accurately by finding the wt. of water required to fill it. This has many disadvantages, especially if there is no simple numerical relation between them. To establish such a relation, the originators of the metric system defined the kg. as the mass of water which occupies one cu. decimeter at its temp. of max. d.; so that the unit of vol., the liter, could be defined either as a cu. decimeter or as the space occupied by a kg. of water at the specified temp. A cu. decimeter of water was not a practical standard wt., and the kg. was therefore redefined as the mass of a particular standard wt. (*kilogram des Archives*). In accordance with this change, the liter was redefined as the vol. occupied by one kg. of pure water at its temp. of max. d. and under normal atmospheric press. Thus the liter became independent of the metric unit of length, and the cu. centimeter lost its relation to the vol. of a mass of water. The relation between the liter and the cc. was found experimentally to be 1 liter = 1000.027 cc. ($\pm$0.001), a difference so small as to be negligible for ordinary glassware. The introduction of the Mohr system caused confusion, inasmuch as by it the unit vol. was defined in terms of the apparent wt. in air of a mass of water at room temp. By this system a liter flask contains 1000 gm. of water (weighed in air against brass wt.) at 17.5°C, which is the equivalent of 1002 cc. as defined above.;

but the followers of Mohr designated the vol. occupied by 1000 gm. of water one liter, and $^1/_{1000}$ part of it one cc. The exact relation between the Mohr unit and the milliliter is given by the fact that the amount of water which weighs 1000 gm. in air of density 0.0012 gm./ml., when weighed against brass wts. of density 8.4 gm./ml., occupies a vol. of 1002.021 ml. at 60°F. The difference between this fig. and 1002, namely, 2 pts. in 100,000, is negligible in practice, and hence the Comm. recommends the adoption of the round number, thus facilitating inter-conversion of "g. w. a," and milliliters. The Comm. has also considered the accuracy of volumetric glassware, and recommends adoption of only two grades: Class A, or standard app., and Class B, or commercial grade app. The Class A Tests and the Class B Tests of the Nat. Phys. Lab. are approved. The Comm. urges that volumetric glassware should never be ordered without specifying the limits of accuracy required. O. P. R. O.

Heat losses from steam-line pipes. R. H. HEILMAN. *Blast Fur. Steel Plant*, **10**, 261–5(1922).—Data are given on bare pipes operating at temps. up to 427 together with curves and formulas, enabling ready solution of problems encountered in the calcn. of heat losses from bare and covered pipes. The general formula giving good results is $T_d = 272.5h/[h + 564/D^{0.10}]$. T_d = temp. difference between canvas surface and room (°F); h = total B. t. u. loss per hr. per sq. ft. of canvas; and D = outer surface diam. (inches). An example is given. W. H. B. (*C. A.*)

High-temperature electric furnace. ANON. *Chem. Met. Eng.*, **29**, 1149(1923); 1 illus.—A furnace was designed with solid graphite resistors. A special low-voltage transformer of large capacity is used. A high power input makes the necessary high temp. easily attainable, after which the power input is reduced to the working rate. The graphite resistors have a rather short life, which may be increased slightly by the injection of a small amt. of illuminating gas into the high-temp. chamber.
W. H. B. (*C. A.*)

BOOKS

Reference List of Bibliographies: Chemistry, Chemical Technology and Chemical Engineering Published since 1900. Compiled by Julian A. Sohon and W. L. Schaaf. New York: H. W. Wilson Co. 100 pp. $1.50. Reviewed in *Ind. Eng. Chem.*, **16**, 543 (1924). (*C. A.*)

HAINBACH, RUDOLPH: **Pottery Decorating.** New York: D. Van Nostrand Co. 2nd ed., revised. 256 pp. $3.00. (*C. A.*)

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ABBREVIATIONS USED IN INDEX

abs.	absolute
a. c.	alternating current
alk.	alkaline
amt.	amount
anal.	analysis
app.	apparatus
approx.	approximate, approximately
at. wt.	atomic weight
av.	average
b. p.	boiling point
B. t. u.	British thermal units
bldg.	building
Brit.	British
cal.	calory(ies)
calc.	calculate
calcd.	calculated
calcg.	calculating
calcn.	calculation
Can.	Canada
cc.	cubic centimeters
ceram.	ceramics
charac.	characteristics
chem.	chemical (not chemistry)
cm.	centimeter(s)
circ.	circular
Co.	Company
Comm.	Committee
coeff.	coefficient
compd.	compound
compn.	composition
concd.	concentrated
concn.	concentration
condy.	conductivity
const.	constant
contd.	contained
contg.	containing
c. p.	chemically pure
cryst.	crystalline (not crystallize)
crystd.	crystallized
cu. m.	cubic meter(s)
d.	density
d. c.	direct current
decompn.	decomposition
det.	determine
detd.	determined
detg.	determining
detn.	determination
dil.	dilute
econ.	economical
ed.	educational
elec.	electric, electrical
e. m. f.	electromotive force
equil.	equilibrium
equiv.	equivalent
est.	estimate
estd.	estimated
estg.	estimating
estn.	estimation
evap.	evaporate
evapd.	evaporated
evapg.	evaporating
evapn.	evaporation
examd.	examined
examg.	examining
examn.	examination
expt.	experiment
exptl.	experimental
ext.	extract
extd.	extracted
extg.	extracting
extn.	extraction
f. p.	freezing point
ft.	foot, feet
fund.	fundamental
fur.	furnace
gen.	general
g.	gram(s)
htg.	heating
h. p.	horsepower
hr.	hour
in.	inch(es)
indus.	industrial
inorg.	inorganic
insol.	insoluble
invest.	investigation
kg.	kilogram(s)
kw.	kilowatt(s)
l.	liter(s)
lab.	laboratory
lb.	pound(s)
lit.	literature

mach.	machinery, machine
mat.	material
m.	meter(s)
manuf.	manufacture
max.	maximum
mfg.	manufacturing
meas.	measure, measurement
mech.	mechanical
mg.	milligram
min.	minute(s)
mixt.	mixture
mol.	molecule, molecular
mol. wt.	molecular weight
m. p.	melting point
N	normal
org.	organic
oper.	operate
operg.	operating
opern.	operation
p. d.	potential difference
phys.	physical
physiol.	physiological
Port.	Portland
powd.	powdered
prac.	practical
ppt.	precipitate
pptd.	precipitated
pptg.	precipitating
pptn.	precipitation
prep.	prepare
prepd.	prepared
prepg.	preparing
prepn.	preparation
press.	pressure
prob.	problem
qual.	qualitative
quant.	quantitative
ref.	reference
refrac.	refractory
rept.	report
resis.	resisting
resist.	resistance
resp.	respectively
r. p. m.	revolutions per minute
sat.	saturate
satd.	saturated
satg.	saturating
satn.	saturation
scien.	scientifically, scientific
sec.	second(s)
sep.	separate
sepd.	separated
sepg.	separating
sepn.	separation
sol.	soluble
soln.	solution
soly.	solubility
sp.	specific
sp. gr.	specific gravity
specif.	specifications
sq. cm.	square centimeter(s)
stand.	standard
subs.	substance
temp.	temperature
tent.	tentative
v.	volt(s)
vol.	volume (not volatile)
wt.	weight

Ceramic Abstracts

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Ross C. Purdy, *Editor*
Emily C. Van Schoick, *Assistant Editor*

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THE EFFECT OF SOUTHERN KAOLINS ON THE LIFE OF SAGGERS

During the past two years there has been ever increasing demand for high aluminous clays for use in the manufacture of high grade refractories. There is a very good reason for this condition. Several of the leading manufacturers of fire brick have found after extensive factory tests that refractory brick made from the kaolins of South Carolina and Georgia are a much higher grade of brick than those made from the ordinary mixtures.

Surely one should expect to get the same excellent results when these kaolins are used in saggers, but this has not always been the experience of potters. This is due to the fact that the fire brick are fired to cone 14 to 16 while the average sagger is burned at cone 7 to 12.

It must be remembered that nearly all kaolins from South Carolina and Georgia have a very low mechanical strength at cone 7 to 12, and continue to shrink on refiring with resulting inferior product when compared with the results obtained by fire brick manufacturers from these clays.

"Dixie" sagger clay is a vastly different type of kaolin. It is a high grade refractory kaolin fusing at cone 35, having an alumina content of 38.51%, a low free silica content, and a low content of iron. It differs from all other kaolins in that it has a very high mechanical strength at cone 7 to 12; reaches its maximum shrinkage at about cone 11, and does not shrink again on refiring with the result that it greatly increases the life of saggers.

"Dixie" sagger clay is shipped from a pile, most of which has been weathered from two to five years. This insures the highest possible plasticity and working qualities in the clay state.

"Dixie" sagger clay is not just a top clay, thrown out because it is badly stained with iron, but it is selected from all parts of our large clay deposit. We can ship you a top clay from our mines in Georgia or South Carolina at a less price and one comparable with the best Southern sagger clays on the market, but we do not recommend their use because they are too high in iron, silica and other impurities; also they do not have sufficient mechanical strength at low temperatures, and shrink on refiring.

A commercial test of "DIXIE SAGGER CLAY" will show the above facts to be true.

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BULLETIN

of the

American Ceramic Society

A Monthly Publication Devoted to Proceedings
of the Society, Discussions of Plant Problems, Discussions
of Technical, Scientific and Art Questions and
Promotion of Coöperative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

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Vol. 3 December, 1924 No. 12

EDITORIAL

THIRTY YEARS OF COÖPERATIVE CERAMICS

From prehistoric times ceramic wares have been essential to man's welfare. He builded his abodes, fashioned his utensils, expressed his art and recorded his achievements in clay and glass. With civilization, ceramics advanced and retarded. With changes in local ideals and customs ceramics changed, but the art of ceramics and ceramics as the medium of art expression was at no time lost to the world; each advance was permanent. Utility and art were never divorced. With the discovery that clay could be fashioned and its form made permanent by firing, clay vessels were home utensils and home utensils were home decorations. Glass may have been formed first by chance but it was not by chance that the history of glass-making parallels the history of art and civilization. Ceramic wares have in all ages been essential to man's material and spiritual welfare, but their production was by individuals, each building into his ware his own art inspirations.

Until very recently man was almost wholly individualistic; each was for self. Survival of the fittest was the motivating slogan; coöperation was unknown.

Coöperation became more and more essential as man emerged from serfdom and slavery, and as he produced more and more of what he did not himself consume. Individualism has grown apace with collectivism for no man

can shift onto others his responsibility for self-expression and self-attainments, but man can no longer advance self either at the expense of his fellows, or without his fellows' aid. The complexity of and democracy in human affairs makes it advantageous for men to coöperate. No one in these days has the time and the ability to accomplish or to comprehend all phases of the affairs with which he must now be concerned. This has led to specialization in effort and to coöperation. Coöperation is more selfish than it is altruistic. Coöperation is absolutely essential to an individual's industrial welfare. Coöperation emphasizes individualism, for by coöperation the resources of each individual are manifolded.

As industrial ceramics developed there has been more and more dependence on the coöperation of specialists. No persons working alone could make and market any other than the simplest ware on the smallest possible production basis. Modern production is now on a tonnage basis but with no less demand for quality and art.

Within the last few decades industrial ceramics has developed the demand for specialists who can translate ceramic problems into terms of the fundamental sciences and can keep ceramic science apace with the rapidly growing wealth of scientific facts. This demand brought into existence the modern ceramic schools.

Only thirty years have passed since the world's first collegiate department of ceramic engineering was established. The organizing of the AMERICAN CERAMIC SOCIETY was the next expression of the industrial demand for coöperative development of individuals. Specialists are essentials in the present industrial scheme of affairs, but specialists without an organized means of coöperation would retard rather than progress industrial development.

Coöperation in ceramics is not the carping of an idealist nor the dream words of the altruist; it is the fact realization of those who have builded wisely and largely. It pays individuals to work in the ways provided by the AMERICAN CERAMIC SOCIETY.

PAPERS AND DISCUSSIONS

REFRACTORIES QUESTION BOX

E. E. Ayars, Editor

Question

What simple laboratory tests can be used to keep the quality of refractories up to standard?

Discussion

The simplest test which can be used in a fire-brick plant to maintain the quality of the product is a reheating of the brick to a high temperature. The equipment is simple and easy to operate. A furnace having a combustion chamber about 18 inches each way can be built from brick which are at hand. Kerosene or fuel oil can be used, and a low-pressure burner, preheating coil, and a small blower and motor is all the equipment which it is necessary to purchase. Two hundred dollars should cover the complete investment.

The test consists in placing the brick on end in the furnace and running the heat for five or six hours. Cone 18 is sufficiently high to give an indication of the quality of many brick, but such a furnace should be capable of attaining cone 26.

With most clays, iron is the insidious enemy, and any marked increase in iron content will be quickly shown by the spots developed in the test. A decrease in the refractoriness of the bond clay will be shown by excessive vitrification or by overfiring. An abnormally coarse grind will cause the brick to squat prematurely, and an abnormally fine grind will be shown by early vitrification. Underfired brick will shrink excessively, and inferior clay will swell. Sandy clay will cause the brick to crack.

This reheating is preferable to a fusion test because it is easier to make in the average plant and requires less equipment. Furthermore, it will give more information. A fusion test should also be run at intervals, both on the clay and the brick, but most plants will find that this can be done more cheaply and more accurately at a properly equipped testing laboratory than at the plant. A reheating to cone 20 of brick from different sources, will usually leave no doubt as to which is the superior refractory."—Robert F. Ferguson, Garfield Fire Clay Company.

Question

Will the use of "super-refractories" in boiler furnace work become general?

Discussion

My position on the matter of boiler refractories may be briefly summed

up as follows:[1] While there will undoubtedly be a limited demand for the so-called super-refractories which some of the manufacturers are producing at this time (in other words, refractories capable of withstanding upwards of 3500°F) the prices at which such material is offered make its use prohibitive in ordinary boiler construction and it is up to the user of fire brick to so construct his furnaces that the ordinary first grade refractories will function in a satisfactory manner. The results of this extensive investigation which I have made among large users of fire brick indicate that refractories rarely fail directly from fusion, the main cause of failure being the action of molten slag on the walls which enters the spaces between brick and the pores of the brick itself, causing the refractory particles to form a eutectic with the slag and flow away. This difficulty is very largely accentuated by the fact that the fire brick ordinarily furnished vary in dimensions through considerable limits, making necessary the use in some cases of comparatively large joints; and it is the feeling of the users that the greatest opportunity for improving the quality and increasing the life of commercial refractories lies in greater uniformity of dimensions. This point cannot be too strongly emphasized and it is a matter which has been repeatedly brought to the attention of the manufacturers so far with little in the way of definite results, and I would urge upon your SOCIETY the importance of impressing upon the manufacturers to so regulate their processes of manufacture that the fire brick to be used in furnace linings will have sufficient uniformity in dimensions to permit their being laid up with the use of a minimum of bonding material between courses.

Question

What do you find in the Question Box which has caused you to read to this point? If you have found anything of value during the past few months, it is highly probable that you can contribute questions and discussions that will be interesting to the other readers. Won't you sit down and frame your questions and discuss them. The Editor does not believe that his situation carries with it the duty of writing many discussions of such questions as are put, but rather the selection and compilation of discussions forwarded to him by the readers. Some readers have been very good about making contributions, but we need other viewpoints and experience, and various methods of expression. Address the Editor, care of the General Secretary.

[1] The following extract from personal correspondence was written by an engineer of several years' experience in power plant refractory problems, and at present working with no less than three national associations on the problem of proper boiler furnace refractories.

ACTIVITIES OF THE SOCIETY

NEW MEMBERS RECEIVED FROM OCTOBER 15 TO NOVEMBER 15

PERSONAL

Anwyl, Robert H., 215–15th Ave., Columbus, Ohio. Student.

Crandall, J. Ralph, 118–14th Ave., Columbus, Ohio. Student.

Eberle, William S., Box 25, Williamstown, W. Va. Secretary and Treasurer, The American Bisque Co.

Hall, John W., 3rd, 2124 Mt. Royal Terrace, Baltimore, Md. Westport Paving Brick Co.

Hayward, Claude C., 6186 Westminister Place, St. Louis, Mo. General Refractories Co.

Johnson, Gustaf A., 612 W. Main St., Maryville, Tenn. Technical Staff, Aluminum Co. of America., Alcoa, Tenn.

Kirk, Brenton S., New Philadelphia, Ohio. Superintendent, The Belmont Stamping & Enameling Co.

Lower, Donald E., 1942 Iuka Ave., Columbus, Ohio. Student.

Morgan, James W., Jackson, Ohio. Secretary-Treasurer, The Morgan Horton Clay Co., Eifort, Ohio.

Smith, Kenneth M., 213 N. 11th St., Cambridge, Ohio. Ceramic Engineer, Cambridge Sanitary Mfg. Co.

Yancey, Mary L., 304 Russell Ave., Ames, Iowa. Instructor in decorative pottery at Iowa State College.

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	Personal	Corporation
George A. Balz		1
Paul E. Cox	1	
J. C. Hostetter		1
R. K. Hursh	1	
F. G. Jackson	1	
L. W. Manion	1	
Office	7	
Total	11	2

MEETING OF PORTLAND CERAMISTS

On Friday evening, October 16, two dozen Portland, Oregon clayworkers and friends assembled at an informal dinner in the Multnomah Hotel, one of Portland's leading hostelries. This gathering was complimentary to Mr. and Mrs. Ross C. Purdy of Columbus, Ohio, at the end of their two-days' visit to this most attractive and thriving seaport of the Pacific Northwest.

Secretary and Mrs. Purdy were on their return trip to Columbus from attendance at the Summer Meeting of the AMERICAN CERAMIC SOCIETY in Los Angeles, October 6 and 7. Wednesday and Thursday, October 15 and 16, were spent in Portland. The first of the two days was devoted entirely to seeing the city and to an automobile ride of a little less than one hundred miles over one of the most scenic portions of the celebrated Columbia River Highway. This highway is a paved boulevard for close to two hundred miles through the depths of the canyon of the Columbia River. The party was piloted on this day by Raymond R. Smith, of the Denny-Renton Clay and Coal Company, M. L. Bryan, of Columbia Terra Cotta Company and Ira A. Williams, Consulting Geologist, all former acquaintances of Mr. and Mrs. Purdy.

The second day, Thursday, October 16, was given to plant visitations in and about Portland. Among the factories visited were Standard Brick and Tile Company, through the courtesy of A. H. Wethey, Jr., President; Pacific Stoneware Co., T. S. Mann, President; Sewer-pipe Plant of Denny-Renton Clay and Coal Co., enameling department of the Portland Stove Works, and the plant of the Columbia Terra Cotta Company in Vancouver, Washington, owned and operated by M. L. Bryan.

Ira A. Williams, who has long been identified with the ceramic industries in both middle and western states, presided at the get-together dinner in the evening at the Multnomah Hotel. Mr. Purdy, in his customary apt and entertaining way, told of the growth and activities of the AMERICAN CERAMIC SOCIETY, and spoke of the needs of the industries which it represents. The desirability of conducting technical research along various ceramic lines was emphasized, and attention called to the importance and necessity of every one contributing freely of their own experience in the advancement of the business of the individual and of the ceramic industries as a whole.

The following persons were present at the dinner, eight of whom are members of the AMERICAN CERAMIC SOCIETY:

Mr. and Mrs. Ross C. Purdy, Columbus, Ohio
H. C. Elliott, Cascade China Company, Portland
Mr. and Mrs. M. L. Bryan, Columbia Terra Cotta Company, Vancouver, Wash.
Mr. and Mrs. T. S. Mann, Pacific Stoneware Company, Portland
Mr. and Mrs. A. H. Wethey, Jr., Standard Brick and Tile Company, Portland
F. J. Pohs, Portland Stove Works, Portland
Mr. and Mrs. H. R. Kreitzer, Columbia Brick Works, Portland
Mr. and Mrs. O. K. Edwards, Face Brick and Tile Mfr., Portland
Mr. and Mrs. J. E. Walling, Denny-Renton Clay and Coal Company, Portland
W. Foster Hidden, Common Brick Mfr., Vancouver, Wash.
Mr. and Mrs. L. A. Martin, Columbia Terra Cotta Company, Vancouver, Wash.,
L. E. Kern, Kern Clay Products Company, Portland
J. F. Straumford, Denny-Renton Clay and Coal Company, Portland
Miss Ersel Foron, Campbell Hill Hotel, Portland
Ira A. Williams, Consulting Geologist, Portland

MEETING OF ST. LOUIS SECTION[1]

A joint meeting of the St. Louis chapter of the American Institute of Architects, and the St. Louis Section of the AMERICAN CERAMIC SOCIETY was held at Washington University, Tuesday evening, October 28.

As usual, this was a dinner meeting and was held in the dining room at Washington University. The attendance of both Societies was evenly divided. The meeting was

[1] By F. E. Bausch, Chairman.

exceedingly interesting and enthusiastic. Wm. A. Hirsch, President of the St. Louis Chapter of American Institute of Architects presided and the various speakers of the evening were introduced by F. E. Bausch, Chairman of the St. Louis Section of the SOCIETY. Preceding the meeting, there was an inspection of an exhibition of polychrome and pulsichrome terra cotta by the two local terra cotta companies, namely, the St. Louis Terra Cotta Co., and the Winkel Terra Cotta Co.

W. T. Doyle, manager of the Terra Cotta Service Bureau of Chicago, made an excellent talk on the purpose of the Terra Cotta Service Bureau and its efforts in behalf of standardization of the work; also the promotion of a better understanding between the manufacturer and the user of terra cotta. An interesting discussion followed on this paper by some of the best known local architects, namely, Messrs. Mauran of Mauran, Russell, Crowell; Mr. LaBeaume and J. P. Jamieson, of the firm of architects who designed the buildings comprising the Washington University group. C. E. Klipstein who was on the program was not able to appear.

Prof. G. Ferrand, School of Architecture, made a very interesting talk on the splendid facilities and equipment of Washington University in connection with a contemplated course in ceramics, inasmuch as the University has an exceptionally good chemistry department and a new building is just being erected for a geology department. The laboratory is well-equipped with machines for testing materials.

There are various industries established in St. Louis where also the raw materials are secured which would enable ceramic students to come into intimate contact with the commercial product.

November Meeting of St. Louis Section

The members of the St. Louis Section of the SOCIETY held their November meeting on the evening of November 25. A dinner was served preceding the meeting which was held at the American Annex Hotel. Among the papers was, "Something New in Enameling—Grained Mahogany" presented by E. Eizenbrot of the Buck Stove and Range Co., who displayed specimens of his work as illustrations. F. G. Jaeger, President of the Superior Enamel Products Company, talked on "How Porcelain Enamel Signs Are Made."

NOTES AND NEWS

PRESIDENT LANDRUM HONORED AT DINNER

On Monday night, November 3, R. A. Weaver, Editor of *The Enamelist* and President of the Ferro Enamel Supply Company, gave a dinner at the University Club of Cleveland, in honor of R. D. Landrum, Vice-President of the Vitreous Enameling Company of Cleveland and also President of the AMERICAN CERAMIC SOCIETY.

Everyone thoroughly enjoyed the dinner after which Mr. Landrum made a few remarks regarding the past and future of the enameling industry and pointed out that every year new fields were being opened to the enameling trade.

He pointed out that when he first entered the business as a chemist for the Lisk Manufacturing Company that the only field open at that time was the kitchenware field with some little business in the bathtub industry. Since then all kitchens have been completely enameled with such items as gas ranges, coal ranges, refrigerators, table tops; kitchen cabinets being largely finished in porcelain. Bathrooms are completely finished in porcelain and the next step is to use porcelain to a large degree in basements. This is

being done by such concerns as the American Radiator Company who are advertising very largely the idea of having heating equipment housed in porcelain.

The following men who are interested in enameling were present at the dinner: R. D. Landrum and John Grainer from Vitreous Enameling Company, H. D. Cushman, J. D. Henry, H. C. Luebbert and R. L. Williams of the Ferro Enameling Company, Carl W. Mehling of The American Radiator Company of Buffalo, Paul Francais of The National Division of the American Stove Company, L. W. Manion of Canton, E. B. Prentice and H. F. Chrisman of The Massillon Refractories Company of Massillon, C. A. Blackburn and H. E. Barker of The Cleveland Metal Products Company, R. A. Weaver, H. E. Ebright, Paul Quay, H. L. Brooks, E. L. Stine, A. T. Davis, J. E. Rumer, Major Wilfred Mavor and R. A. Nelson of The Ferro Enamel Supply Company, H. E. Johnson of The Cincinnati Enameling Company, F. P. Allen of The Enamel Products Company, W. H. Wilson of The Lewis-Shepard Company, S. M. Jenkins of The Celite Products Company, F. G. Thorpe of The Brown Instrument Company, H. M. Richards of The American Rolling Mill Company and J. C. DeVol of The A. B. Stove Company.

After the dinner the entire crowd was entertained at the theatre, as guests of Mr. Weaver.

DEDICATION OF NEW CERAMICS BUILDING

Georgia School of Technology in Formal Opening

The first ceramic building south of the Ohio river was officially opened at Georgia Tech on Saturday morning, Nov. 15, when Prof. Watts, head of the ceramics department of Ohio State University, made his address on "Ceramic Resources in Georgia."

DR. M. L. BRITTAIN, PRES.
Formerly Supt. of Education of Ga. and Supt. of Public Schools of Atlanta.

The address was the outstanding feature of the exercises, followed by a luncheon given by M. L. Brittain to fifty prominent ceramic engineers of the south.

In addition to the ceramic experts of the south, many prominent educators were present. Among them was Chancellor Kirkland, of Vanderbilt University.

Course at Georgia Tech.

Ceramic instruction at Georgia Tech. was accomplished through support given the institution by the Atlanta Chamber of Commerce and Fulton County. Last year, under the leadership of George Carswell, President of the Senate, the Georgia legislature gave the school an annual maintenance fund of $10,000.

Courses of instruction at Georgia Tech cover a period of four years and lead to the degree of bachelor of science in ceramic engineering. A graduate of the department, according to A. V. Henry, in charge of the work at Tech must possess the basic knowledge which would enable him to prospect for raw materials and to carry them through the process of manufacture to the finished product.

The ceramics building is a one-and-a-half-story structure, 50 feet wide and 83 feet long, and is constructed of brick and terra cotta. It contains an office, library, classroom, testing laboratory, clay machinery room and kiln room.

Equipment of School

The testing laboratory is provided with balances, ball mills, molds, electric drier, electric oxidation furnace, a modulus of rupture testing machine and complete microscopic equipment.

In the clay machinery room may be found an emery wheel, jaw crusher, dry pan, pulverizer, rolls, auger machine, turning lathe, potter's wheel, jigger and complete

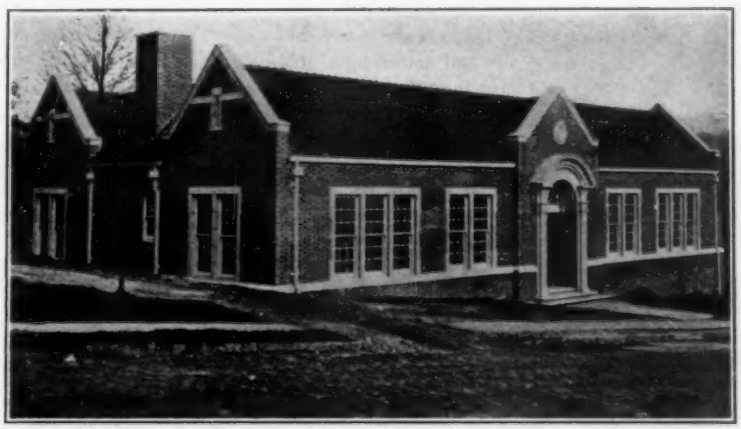

FIG. 2.—New Ceramics Building.

semi-commercial clay washer. The kiln room equipment consists of two experimental gas-fired kilns using induced draft, a pot furnace, a small muffle test furnace, a gas-fired drier, potentiometers and recording pyrometer.

Completion of the new building by the state of Georgia will enable students to combine the theoretical and practical aspects of ceramic engineering. Georgia contains vast beds of ceramic materials, including clays, kaolins, bauxites, feldspars, sands, cement rock and fullers' earth, and special inspection trips have been arranged by the department for juniors and seniors.

A. F. Greaves-Walker, head of the department of ceramic engineering, North Carolina State College, represented the AMERICAN CERAMIC SOCIETY at this meeting.

ADDRESS BY A. S. WATTS, AT DEDICATION OF NEW CERAMICS DEPARTMENT BUILDING

Prof. Watts in part said that a fair return on the investment may rightfully be expected from this school. A department of ceramics is especially unfortunate or fortu-

nate, according to viewpoint, because it has so many fields in which its service may be helpful. According to the various viewpoints it must solve ceramic problems, improve processes, lower cost of production, find new materials, improve products and train men to be superintendents and managers. It would be false to expect in a four-year course of instruction, to train men to be accomplished in all these things. The school must furnish the training as best it can and pass the men to the industries for completion of their education.

Before a young man can become useful industrially he must acquire industrial vision through direct contact with industry. He who accepts a position of responsibility without this vision and with only a theoretical education is courting disappointment.

Ceramic industries need men who can apply science fundamentals to problems of plant control and production.

The greatest drawbacks to progress in the ceramic industries are tradition and misunderstanding. The solution is coöperation between the schools and the manufacturers in providing for and requiring plant experience in the summer periods while the ceramic student is in school.

The ceramic resources of Georgia are many and varied: surface clays for common brick, hollow block, drain tile and sewer pipe; white clays and fluxing materials for face brick; and refractory clays for refractories. The white brick may be salt glazed. Terra cotta and sanitary ware may be made here and also glass. Pottery and faience tile are possible here. All of these require development of the sort in which a department of ceramics may be helpful. It requires more than raw materials. It must have proper buildings, equipment, processing, factory control and trained artisans.

The ceramic school will train men to explore the ceramic material resources of the state, to determine the methods and mixtures. They will be trained in ceramic processing. But this school should not attempt the training of artisans. Technical schools should not be made into trade schools nor trade schools into technical schools.

Manufacturers should establish fellowships here for the conducting of researches under the joint direction of the instructors and the manufacturers. Under such arrangements the student would receive a salary of about three hundred dollars from the manufacturer. This has served to (1) increase information; (2) give the student valuable industrial contact; (3) enable him to complete his education on money earned; and (4) enable the employer to determine the availability of the student for usefulness in his organization.

In closing Prof. Watts outlined ten specific endeavors the doing of even a few of which he averred would amply repay the investment here begun.

REPORT OF PROF. GREAVES-WALKER ON GEORGIA TECH DEDICATION

There were only fifty invitations issued and practically every one was accepted. The guests consisted principally of the clayworkers of Georgia and others interested in ceramics in the state who had made donations of money and materials that made the building possible. North Carolina State, Alabama Poly and University of Alabama were the colleges represented.

Due to the funeral of Dean Emerson of Tech which was held in the morning, the ceremonies were delayed an hour and a half and were therefore limited to the speech of Prof. A. S. Watts, the speaker of the day. Prof. Watts was introduced by President Brittain who in a few short remarks gave the history of the creation of the department

and told of the help received from the industries of the state. Prof. Watts' speech was interesting and enthusiastically received. President Downs of the Central of Georgia Ry. and Lieut.-Governor Carswell were then called on for a few remarks after which the guests were entertained at luncheon by President Brittain.

After lunch the guests were taken to Grant Field to witness the football game between Tech and Vanderbilt as guests of the Tech faculty. This ended the program.

The new department has a fine building and splendid equipment. The building is one story and basement, built of red brick donated by the Stephenson Co., Birmingham, Ala. It has a white stone trim and a tile roof. The roofing tile were donated by B. Mifflin Hood, Atlanta. All of the rooms and halls are floored with tile and wainscoted with the same material. The tile were also donated by Hood. In the furnace room are two down-draft, gas-fired test kilns and a load furnace. On the same floor is also located the office, a classroom, a library and two laboratory rooms.

In the basement is the heavy equipment consisting of auger machine, cutter, pan, small crushers, clay washing plant, filter press and potters wheel. Taken altogether, Tech has a promising start.

NECROLOGY

Otto W. Will

Otto W. Will, Superintendent of the ceramic color department of the Roessler and Hasslacher Chemical Company of Perth Amboy, N. J. and member of the AMERICAN CERAMIC SOCIETY since 1919, died on October 30, 1924. Mr. Will was born at Braubach a/Rhein, Dec. 25, 1868 and came to America in 1888. His early education and preparatory work for taking up the medical profession was completed in Germany. In 1891 he took up his work with The Roessler and Hasslacher Co., where he remained until his death. He is survived by his widow, four sons and two brothers.

OTTO W. WILL

FURTHER NOTES ON CERAMIC SCHOOLS[1]

North Carolina State College

North Carolina State College which has organized a Department of Ceramic Engineering under the leadership of Prof. Greaves-Walker reports the following class enrollment for this year: 4 Freshmen, 2 Sophomores, 1 Junior and 1 Senior. The Freshmen and Sophomores are registered for Ceramic Engineering and will get their first ceramic work next year. The Juniors will get their degrees in the department in which they originally registered but will take what ceramic courses they can substitute in the Senior year. Two Seniors are getting what ceramics they can by working 12 hours per week on two research problems that are being carried on by the department. This is in addition to their regular senior work. These students are either registered in the department or are taking all of the ceramic work which can be offered this year

[1] See "Notes on Ceramic Schools," *Bull.* **3** [11] 458–60.

preparatory to going into the industry. A description of the correspondence course in ceramic engineering at North Carolina State College follows on page 474.—By PROF. A. F. GREAVES-WALKER, Head of Department of Ceramic Engineering.

The University of North Dakota

The primary object of the ceramic department of the University of North Dakota is to aid in research work on the high grade clays of the state. For economic and technical reasons this research work was coupled with that of instruction, thereby utilizing the equipment, the laboratories, the technical force and the work of advanced students in both the educational and research problems.

No special degree is given in ceramic engineering, but students in mining and industrial engineering, and in other lines, are given an opportunity to take some of these technical studies as ceramic electives. The work offered in connection with the ceramic department covers two years. The enrollment is limited to sixty which is as many as can be efficiently handled in connection with the research work and present facilities and staff.—By MARGARET K. CABLE, Asst. Professor of Ceramics.

Newcomb School of Art

	1923–24	1924–25
Total	25	28
Ceramic Decoration	3	11
Making of Pottery and Glaze, Firing	22	17

Seniors: Edith Hohn, Juanita Gonzales Graduate: Elizabeth Davis, Phyllis Reeves.
—By MARY G. SHEERER, Professor of Ceramic Decoration.

NORTH CAROLINA STATE COLLEGE OFFERS CORRESPONDENCE COURSES IN CERAMIC ENGINEERING

New Department of Ceramic Engineering to Pioneer in This Field

In accordance with its purpose to be of the utmost service to the industries of the state and country, North Carolina State College through the College Extension Department has decided to add Ceramic Engineering to its correspondence courses. These courses will carry college credits.

With the knowledge that very little has been done for the growing ceramic industries of the state and that there are a great number of clayworkers in North Carolina and the rest of the country who are desirous of broadening their knowledge of the technical side of ceramics, but have little opportunity to do so, the new Department of Ceramic Engineering, under the direction of Professor A. F. Greaves-Walker, is planning to reach and assist the practical man in every way possible. Realizing that graduates of the department will not be available for four years and will then require practical training before being of any great value to the industries of the state, an Extension program for the clayworker has been laid out which includes a week's instruction in clayworking and ceramics each year and the correspondence courses. These are open to the clayworkers of the entire country.

The correspondence courses to be offered with the credits given are as follows:

1. History of Ceramics (1 credit)
2. Physical Geology (2 credits)
3. Occurrence and Properties of Clays (3 credits)

4. Mining and Preparation of Ceramic Materials (3 credits)
5. Explosives (1 credit)
6. Forming Ceramic Wares (2 credits)
7. Driers and Drying (3 credits)
8. Kilns and Burning (3 credits)
9. Setting Heavy Clay Products (1 credit)
10. Ceramic Calculations (3 credits)
11. Ceramic Designing (3 credits)
12. Feldspars and Kaolins (2 credits)
13. Refractories and Furnaces (2 credits)
14. Pyrometry (1 credit)

As the courses are designed primarily for the present needs of the clayworkers and miners of North Carolina, they will include, for the present, instruction covering heavy clay products only. Other courses may be added later as the need and demand appears.

It is expected that Courses 7, covering Driers and Drying, and 8, covering Kilns and Burning, will be ready in late December or early January. The other courses will be given as a sufficient number of students register for them.

The fees will be based upon the credits given for the completion of each course, two dollars and a half per credit being charged. Thus a three-credit course will carry a fee of seven dollars and fifty cents.

A bulletin describing these courses as well as those offered by other departments of North Carolina State College has been issued and may be had upon application.

NORTH CAROLINA CLAYWORKERS ORGANIZE

At an enthusiastic two-day session held during the week of Nov. 9, 1924, at the Vance Hotel, Statesville, N. C., the clayworkers of the state perfected a permanent organization to be known as the North Carolina Clayworkers Association.

The objects of the Association are educational, the principal ones being: the improvement of plant processes and products, the dissemination of information regarding clay products, and the advancement of the Department of Ceramic Engineering at North Carolina State College.

The officers elected were: President, Frank Daniels, Goldsboro; 1st Vice-President, N. B. Kendrick, Mt. Holly; 2nd Vice-President, J. D. Johnson, Raleigh; Secretary-Treasurer, Prof. A. F. Greaves-Walker, State College, Raleigh; Member Executive Committee, George M. Norwood, Raleigh.

Committees were appointed on freight rates, membership, trade schools, and advancement of Department of Ceramic Engineering, State College.

A committee to act in an advisory capacity to the Department of Ceramic Engineering, composed of Frank R. Daniels, T. H. Holmes, and George M. Norwood, was also appointed.

Prof. Greaves-Walker made a preliminary report on the clay, shale and kaolin resources of the state and predicted an era of ceramic development in the Piedmont region in the immediate future. He also announced that State College would offer a short course in Clayworking and Ceramics, January 12–16, 1925, and was now offering correspondence courses in fourteen ceramic engineering subjects. This is the first time ceramic engineering subjects have ever been offered by correspondence.

Theodore A. Randall, for thirty-nine years Secretary of the National Brickmakers

Association, with headquarters at Indianapolis, Ind., was among the guests at the convention.

The next quarterly meeting of the Association will be held in Raleigh, during the week of January 12, 1925.

SHORT COURSE IN CERAMICS AT NEWELL, W. VA.

The second year of ceramic instruction at the Newell High School was begun with the initial session held on Thursday, November 6. The classes as before are arranged for Monday and Thursday, from 7.30 till 9 P.M. The work has made a good beginning with 40 registered students.

The courses given are as follows: Shop Arithmetic and Shop Mechanics, by R. V. Miller; Principles of Ceramics and Ceramic Problems, by J. W. Hepplewhite; Heat and Heat Measurement, by V. J. Roehm; Principles of Economics, by Lester M. Aaron. The instructors are all connected with potteries of this district. Mr. Miller is ceramic chemist with the Knowles, Taylor and Knowles Pottery Co. of East Liverpool, Mr. Hepplewhite is with the E. M. Knowles China Co. of Newell, Mr. Roehm with plant No. 6 of the Homer Laughlin China Co. and Mr. Aaron with plant No. 4 of the same company. With the exception of the last named instructor these men are graduates of Ohio State University. Mr. Aaron is a graduate of Princeton and Harvard.

Much credit is due these men for the work they are doing which involves considerable sacrifice in time and labor. It is a most encouraging sign, however, that the course has the earnest support of the Brotherhood of Operative Potters. The duration of the course is 18 weeks.

EXHIBITS OF CLAY WORKING MACHINERY

The Common Brick Manufacturers Association is providing opportunity in connection with their annual meeting, Drake Hotel, Chicago, February 9–13 for an exhibit of clayworking machinery and supplies. This is the week prior to the Annual Meeting of the AMERICAN CERAMIC SOCIETY in celebration of the world's first collegiate department of ceramic engineering, Columbus, Ohio. There is coöperation between these two organizations to make these exhibits educational in the most effective way.

SOCIETY OF GLASS TECHNOLOGY

The first meeting of the Society of Glass Technology for the session 1924–25 was held in Sheffield on October 15, the President, Col. S. C. Halse, in the chair. An address entitled, "The Present Position of the Glass Industry in North America," was given by W. E. S. Turner, who observed that in America the period of trade depression had not been continuous, as was the case in the United Kingdom. In the autumn of 1922, American trade began to improve, and 1923 was a very good year. In February, 1922, trade in general began to fall off, and a very dull period still persisted.

The cut glass industry had almost entirely died out in America, but colored glass was finding a place more and more. There was a distinct improvement in American taste for glassware. At the Steuben works of the Corning Glass Company some very fine artistic work was being manufactured.

Prof. Turner next referred to the gradual disappearance of pot furnaces in favor of tank furnaces. The latter were now being used even for the manufacture of green and

blue signal lights, and for selenium ruby glass. Electric light bulbs, except in the case of very small or very large bulbs, were now practically all made by machines fed from tank furnaces, the glass being the soda-lime-magnesia type. The tubing required for the completion of the lamp was still of the glass variety.

Several noteworthy advances in the glass industry were then noted. During the past few years there had been a very distinct development in the use of blowing machines or press and blow machines. In this connection reference was made to (1) the Westlake Machine for thin walled tumblers, (2) The Hartford-Empire Machine for electric light bulbs, and (3) the great development in the manufacture of light walled tumblers.

Dealing next with sheet glass, Prof. Turner remarked that the Fourcault process had not as yet achieved any considerable success in America. The cylinder process was still in active operation. An epoch-making operation was that developed at the glass works of the Ford Motor Company. This process marked an absolute departure of the use of pot furnace, as the glass was melted in tanks and there was continuous rolling between a pair of rollers, the sheet passing down a leer about 440 feet long and subsequently, in sheets, traversed long tables in a continuous belt, where the grinding and polishing were done.

With regard to bottle machine there was a tendency to replace the Owens machine in favor of the feeder-fed type. There were no striking advances in feeding devices, the Hartford-Empire Feeder being the most in favor, followed by the W. J. Miller. One novelty in operation was the use of a rotating plunger, especially when large ware was being made.

Prof. Turner then dealt with the problems of furnaces and furnace efficiency. This was one of the foremost problems discussed by glass manufacturers. The average life of a tank furnace operated by machines was 11 to 13 months. A table was presented showing for a number of factories the value of the ratio of fuel consumed to glass melted. Several factories could show a ratio as low as 0.6. In conclusion reference was made to the innovation of the use of heatless leers. A description was given of such leers.

BUREAU OF MINES NOTES

Dolomite for Refractories

The dolomite refractories investigation being conducted by the Department of the Interior at the Ceramic Experiment Station of the Bureau of Mines, Columbus, Ohio, includes a study of the many fluxes which could be used to aid in the dead-burning of dolomite and also a complete survey of the iron oxide-alumina-silica field as fluxes. The temperature of calcination and the resulting properties have been carefully investigated, and the most desirable calcines chosen for further investigation in the making of dolomite brick. Many binders and the several methods in common use of fabricating brick commercially have been tried, and a thorough study has been made of the properties of the most successful ware.

The results of the work of the Bureau of Mines investigators indicate that by employing the proper fluxes in the proper proportions, it is possible to dead-burn dolomite, when properly sized and under proper heat treatment, to a grain that will not slake after long exposure to the air or under the more severe autoclave treatment. Several binders for the ground grains have been found to give promise while two of this number are especially satisfactory. It is possible to make shapes from ground sinter, by both the semi-dry press and slop mold methods, which, when properly fired, will not slake upon prolonged exposure to the weather. The brick thus made have physical properties which indicate that they will probably give good service as a basic refractory.

Details of these investigations looking toward the utilization of dolomite for refractories are given in Serial 2627 by G. A. Bole, copies of which may be obtained from the Department of the Interior, Bureau of Mines, Washington, D. C.

NOTES FROM THE BUREAU OF STANDARDS

The Strength of Hollow Tile and Reinforced Concrete Floor Slabs

The Bureau of Standards, in coöperation with the Hollow Building Tile Association, recently completed a series of tests on specimens of combination hollow tile and reinforced concrete floor slabs, reinforced in but one direction. The tests were planned to determine the extent to which the tile could be relied upon in resisting bending and shearing stresses.

Forty-four slabs, varying from 8 ft. 10 in. to 15 ft. in length, with a total depth of 8 in., and a maximum width of 30 in. were tested. The combination slabs consisted of two 4-in. concrete ribs separated by a single row of tile, laid with their cells parallel to the length of the slabs, and enclosed on each side by a row of tile sections which had been cut to include nearly one-half their original width. In some of these slabs 8 by 12 in. tile were used without a topping, and in others 6 by 12 by 12 in. tile were laid and covered by a 2 in. concrete topping. For comparison 2 in. solid concrete slabs having the same gross sectional area as the composite slabs, and 3 in. solid concrete beams having the same sectional area as the area of the concrete ribs in the composite slabs were tested. A greater amount of tensile reinforcement was used than is ordinarily employed in practice in order to prevent the failure of the steel before high stresses in the concrete and tile had been developed.

The specimens were tested in a vertical-screw beam-testing machine having a capacity of 600,000 pounds. The deformations in the concrete, tile and steel, and the deflections of the slabs were measured as the loads were applied. By changing the positions of the loads, bending and shearing stresses several times greater than working stresses for concrete were developed.

It was found that the bond between the concrete and tile was sufficient to cause the tile to assist materially in resisting both bending and shearing stresses. The value of the tile in beams without a concrete topping was almost directly proportional to the modulus of elasticity of the tile. When medium or hard tile are used, it appears that the shells of the tile which are in contact with the concrete are as effective as an equal width of concrete would be. A report on these tests is now being prepared for publication.

Method for Evaluating the Different Qualities of Clays

The elementary chemical analyses of all clays show the same constituents, but in widely varying proportions. These differences have failed to account for variations in color (raw and fired), working properties, plasticity, absorption, adhesiveness, and refractoriness.

The Bureau of Standards has undertaken the study of clay colloids, into which a part of all the ultimate elements of the clay body enter, by subjecting a standard, commercial, washed white paper and pottery clay, long known for relative uniformity in its properties, to the action of leaching and dispersion with water and dilute reagents to which it may be subjected in its various uses. It has been separated into fractions of relatively greater and less concentration of absorbed basic elements, and into fractions of greater and less colloid content, and of coarser and finer granular composition.

These divisions are to be subjected to all practical tests capable of quantitative evaluation in comparison with the original. It is believed that by a comparative study of the clay with its own definitely controlled modifications and derivatives, increasing and decreasing its plasticity, supsension power, absorption, color and fire behavior, information will be obtained that will be applicable to all other clays and which will lead to new analytical methods for evaluating the different qualities of clays.

Drying Properties of Clays

The Bureau's preliminary work on the investigation of the drying properties of clays has been completed and a report which will include a discussion of the factors affecting the satisfactory drying of clay wares is now being prepared for publication. Lovejoy's classification of clays is used approximately, and successful drying is shown to be a function of the character of the clay and of the rate of drying, involving as factors temperature and humidity of both air and clay, and also size and shape of the clay body. The causes of the various types of drying injuries are also pointed out.

As a result of observations made, the following method is suggested for working out a rapid and safe drying schedule for each type of clay: Successive groups of samples of the particular type of clay under consideration are dried, each group at a rate more rapid than that used in the preceding group. This is continued until the most rapid possible drying rate has been determined, beyond which rate any increase in the temperature or rate of drying results in an excessive and intolerably large percentage of drying injuries to the ware.

Frequent observations of shrinkage during such trials have shown: First, that cessation of drying shrinkage takes place comparatively early in the drying process, and is practically coincident with the completion of the evaporation of the so-called "free water;" second, that after this stage is reached, the drying may be hastened almost as much as desired, so long as baking temperatures are not reached, without appreciably adding to the percentage of drying injuries.

New Method for Bonding Magnesia Refractories

The Bureau's preliminary work with magnesia refractories has indicated a promising method of bonding electrically fused magnesia which will be used in making the first experimental lining for the Bureau's new Detroit electric furnace for steel melting. Eighty-mesh fused magnesia bonded with approximately 20% water-ground fused magnesia burns at 1500 to 1600°C to a satisfactory strength and if properly applied may be used as a firmly adhering facing over commercial magnesite brick.

Ground Coat and White Cover Enamels for Sheet Iron and Steel

An investigation of the relative values of feldspar and quartz as the refractory in white cover enamels for sheet iron and steel has recently been completed. This work was undertaken to determine the effect produced by substituting feldspar for quartz, and quartz for feldspar in commercial types of enamels.

The report on the work which is being prepared for publication will contain the results obtained with three groups of twenty enamels each, in which feldspar-quartz ratios were 60:0, 35:25, and 0:60, the other constituents being changed in quantity and kind. The results indicated in general that: First, increasing the quartz reduced opacity of the enamels, increased their resistance to thermal shock and to action of acid, but produced no marked change in their mechanical strength; second, the effects of increasing the feldspar were not as pronounced as in the former case, but it may be said that a slight decrease in opacity, resistance to acid and thermal shock, and mechanical strength was obtained.

JOHN L. HARPER, THE ENGINEERING GENIUS OF NIAGARA FALLS POWER COMPANY, CALLED BY DEATH

John Lyell Harper, vice-president and chief engineer of the Niagara Falls Power Company, died November 28th. He underwent an operation for appendicitis, but his heart was unable to withstand the rigors of the malady.

An Engineering Genius.—Recognized as one of the greatest of the world's hydro-electric engineering geniuses, Mr. Harper was responsible to a large extent for the development of the Niagara Falls Power Co. He was associated with that concern and its predecessor, the Hydraulic Power & Manufacturing Co., for 22 years, starting in the company's employ as an assistant engineer. He designed and constructed the eleven million dollar extension of the company's mammoth plant which was completed recently and which will remain a monument to his ability as a hydro-electric genius. He also designed other big development works of the company.

Mr. Harper was 51 years old, having been born in Harpersfield, Delaware county, New York, September 21, 1873. He was vice-president and chief engineer of the Harper-Taylor Company, consulting engineers recently organized and in which the Cramps Shipbuilding Company is heavily interested.

J. L. HARPER

Mr. Harper was prominently identified in the membership of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Electrochemical Society, the AMERICAN CERAMIC SOCIETY and the Engineers' Club of New York City.

Four years at Cornell University brought his degree in Mechanical Engineering and in 1898, one year after graduation, he married. His career was marked by the simple progression that stamps the lives of all mortals who achieve the real things in life. He was in charge of the design and of the construction of Hydraulic Station No. 3-A in the gorge below the Falls. In the long stretch of years from 1902 until 1918 under his engineering direction the installed capacity of the great gorge plants grew from 14,000 to 160,000 horse power. During the year 1918 the various power interests were grouped under government direction into a new corporation taking the name of the Niagara Falls Power Company, and Mr. Harper was made its chief engineer.

During the war when there was a serious shortage of power at Niagara Falls and the War Department requested plans for the most economical development to utilize the remaining water available for diversion, it was the Harper plan that met with the approval of the government.

It has been said, and rightly too, that genius is the capacity for taking infinite pains. Such a one was John Lyell Harper. His imagination and his foresight were astonishing. He seemed always to be ready when the time of action came. It is some slight consolation to those who shared his labors that he saw the completion of the latest power plants for they are the children of his mastermind.

CALENDAR OF CONVENTIONS

Organization	Date	Place
AMERICAN CERAMIC SOCIETY (Annual Meeting)	Feb. 16–21, 1925	Columbus, Ohio
Am. Assn. Adv. of Science	Dec. 29, 1924–Jan. 3, 1925	Washington, D. C.
Am. Assn. of Flint and Lime Glass Mfrs. (Annual Meeting)	July, 1925	Atlantic City, N. J.
Am. Soc. for Testing Materials	June 22–26	Atlantic City, N. J.
Am. Concrete Institute	Feb. 24–27, 1925	Chicago, Ill.
Am. Face Brick Assn.	Dec. 2–4, 1924	Hot Springs, Va.
The American Institute	Dec., 1924	New York City
Am. Inst. of Chemical Engrs.	Dec. 3–6, 1924	Pittsburgh, Pa.
Am. Society of Mech. Engrs.	Dec. 1–4, 1924	New York City
Common Brick Mfrs. Assn.	Feb. 9–13, 1925	Chicago, Ill.
Eastern Paving Brick Mfrs. Assn.	Dec., 1924	New York (?)
Exposition of Inventions	Dec. 8–13, 1924	New York City
Hollow Bldg. Tile Assn.	Jan., 1925	Chicago, Ill.
Manufacturing Chemists' Assn.	June, 1925	New York City
Mining & Met. Society of America	Jan. 13, 1925	New York City
Natl. Assn. of Mfrs.	May, 1925	New York City
Natl. Assn. of Mfrs. of Pressed and Blown Glassware	March, 1925	Pittsburgh, Pa.
Natl. Assn. of Stove Mfrs.	May 13–14, 1925	New York City
Natl. Brick Mfrs. Assn.	Jan. 26–31	Washington, D. C.
Natl. Clay Products Industries Assn.	April, 1925	Chicago, Ill.
Natl. Exposition of Power & Mech. Engrs.	Dec. 1–6, 1924	New York City
Natl. Glass Distributors' Assn.	Dec., 1924	Pittsburgh, Pa.
National Lime Association	May, 1925 (?)	
N. J. Clayworkers' Assn. and E. Sec. of the AMERICAN CERAMIC SOCIETY	Dec. 19, 1924	New Brunswick, N. J.
Taylor Society	Dec. 4–6, 1924	New York City
Tenth Exposition of Chem. Industries	Sept. 28–Oct. 3, 1925	New York City
Tile & Mantel Contractors' Assn. of America	Feb. 9, 1925	Louisville, Ky.
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James O. Handy,* Pittsburgh Test Lab., Box 1115, Pittsburgh, Pa.—G.
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Ralph E. Hanna,* 84 Market St., Perth Amboy, N. J.—T. C.
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J. E. Hansen,* Mellon Institute, Pittsburgh, Pa.—E.
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Karl Hart, 111 N. Rugby Ave., Huntington Park, Calif.—R.
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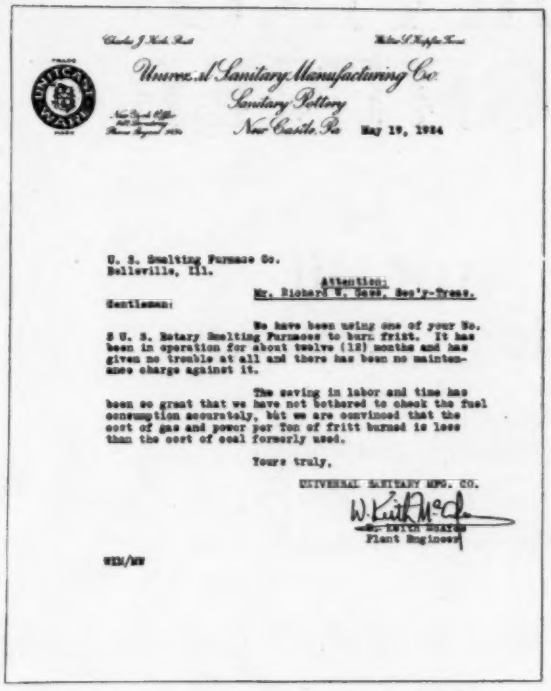

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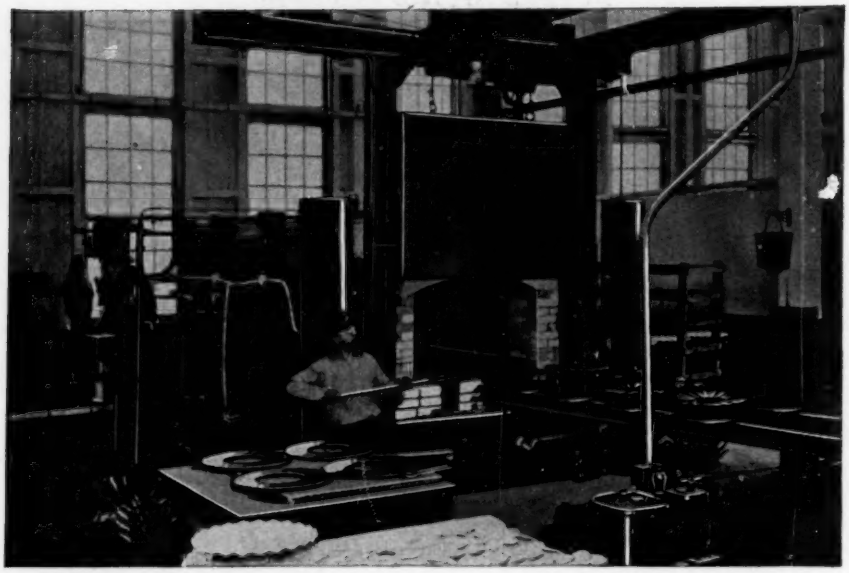

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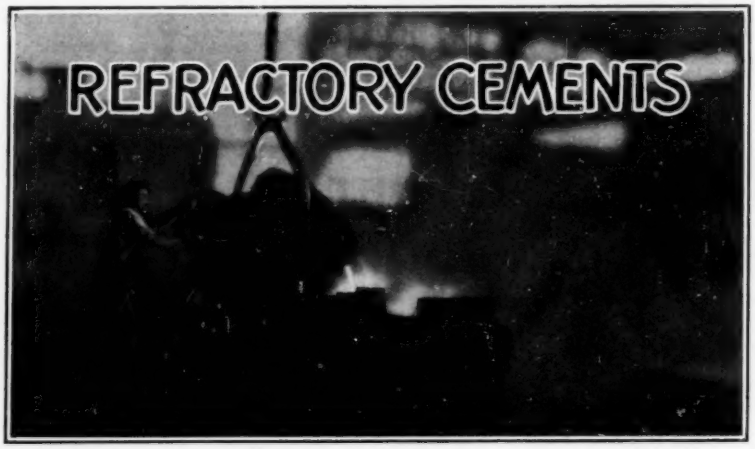

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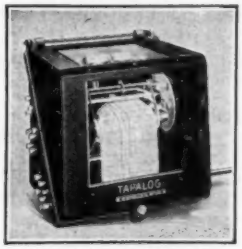

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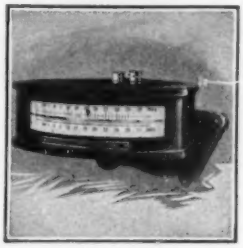

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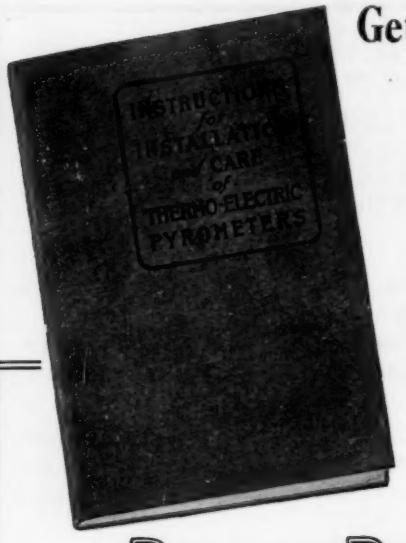

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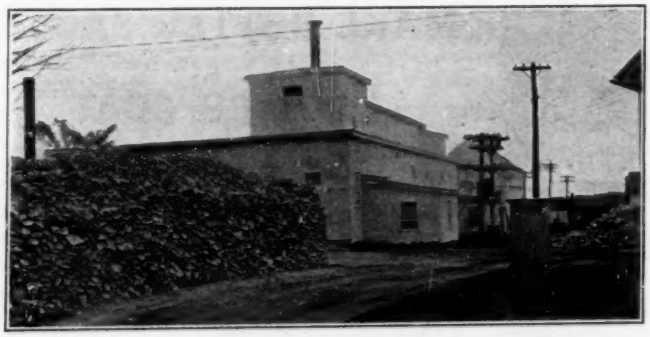

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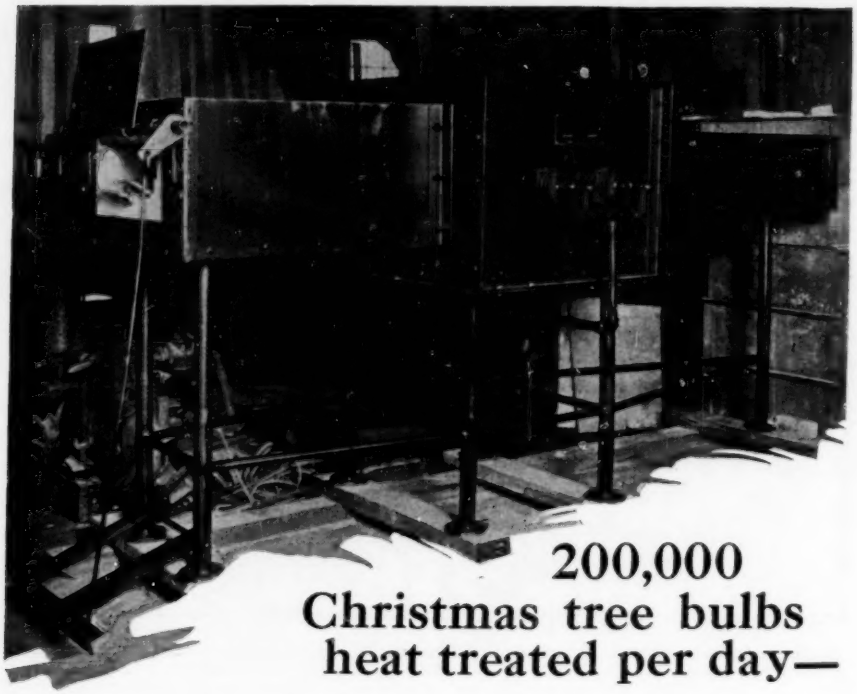

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This Surface Combustion Furnace demonstrates how very delicate work can be handled on a large scale, without sacrificing the good quality workmanship, which, in some cases, can only be obtained at the expense of fast production.

Utilization Division of the COMBUSTION UTILITIES CORPORATION

Whether your production is on a large or small scale, you can gain something by talking over your heat-treating methods with a Surface Combustion engineer. Remember there are now more than ten thousand successful industrial installations made by Surface Combustion Company—this broad experience is within your reach.

Write to our nearest branch office now. State when you would like to show one of our engineers through your factory. He will make a survey of your problems, submit the results to you in portfolio form, and tell you *in black and white* how Surface Combustion can save you money. *Write that letter now!*

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Quality *Uniformity* *Experience*

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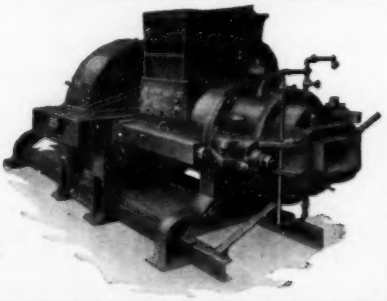

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A request on your letterhead will secure a free copy of this valuable 32-page booklet.

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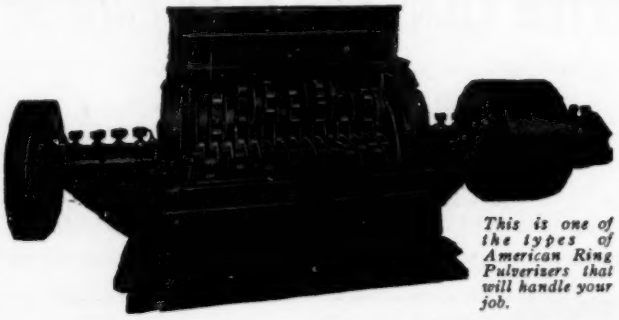

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See how the ring method of crushing brings lower operating cost and an elimination of costly shut-downs.

We assure you that it does an unapproachable job on grog, glass cullets, coal and clay: but don't be convinced by our statement. Ask for the actual facts and figures based on the performance for scores of successful companies.

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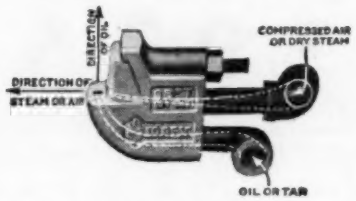

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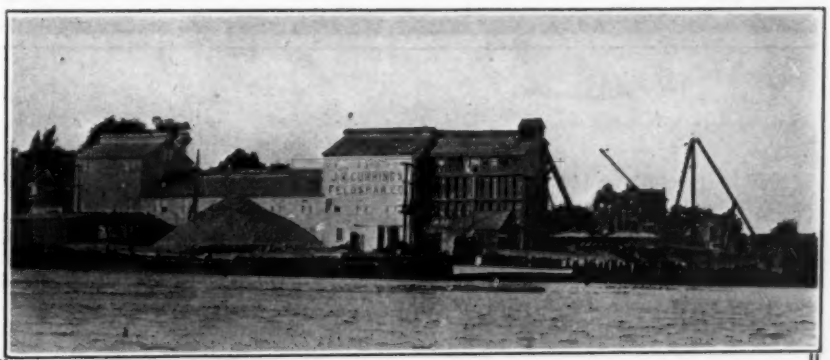

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Interesting data on economies effected under actual plant conditions has been collected and will be a useful guide in planning larger profits for 1925. If you have not yet received full data, we shall be glad to supply it on request.

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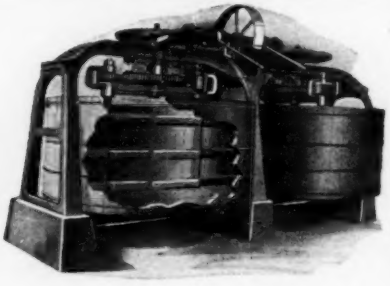

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